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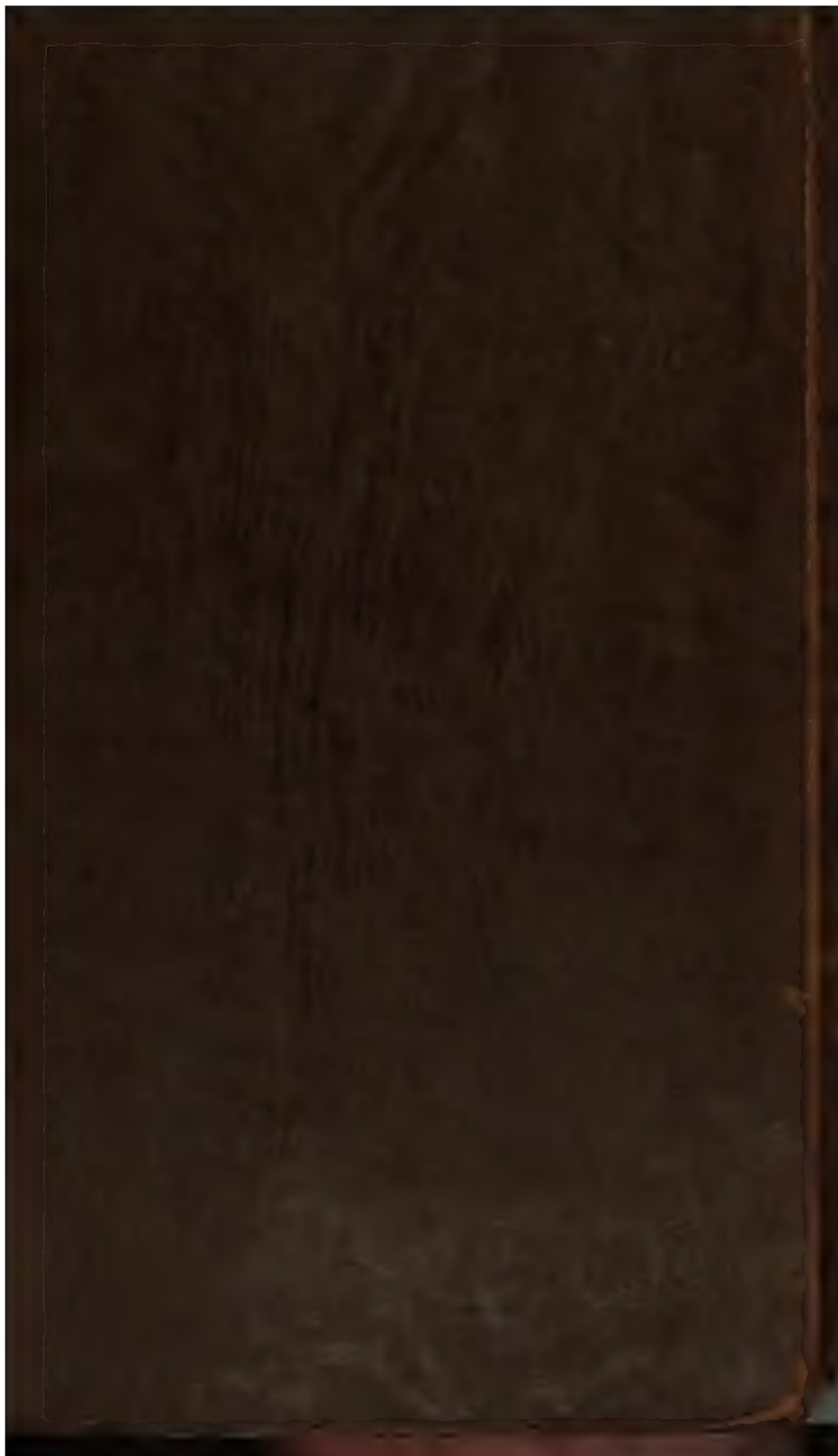
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ELEMENTS OF CHEMISTRY,
AND
NATURAL HISTORY.

TO WHICH IS PREFIXED
THE PHILOSOPHY OF CHEMISTRY.

BY A. F. FOURCROY.

**TRANSLATED FROM THE FOURTH AND LAST EDITION OF THE
ORIGINAL FRENCH WORK,**



BY R. HERON.

IN FOUR VOLUMES.

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1796.



TO

DR. B L A C K.

THIS translation of *Fourcroy's Elements of Chemistry*,
a work which has been honoured with his recommen-
dation of it to the students of Chemistry, is respectul-
ly dedicated, by

His obedient,

And very humble Servant,

THE TRANSLATOR.

EDINBURGH, }
Mar. 4. 1796. }

C O N T E N T S

OF THE

FIRST VOLUME.

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E R R A T A.

Page 460, line 8th, from top; *for* Fluate of Soda, *read* Fluate of Potash.
 460, line 11th, *for* Fluate of Soda, *read* Fluate of Potash.

ADVERTISEMENT.

THE general truths in any science are continually multiplied, as its perfection advances, and as its means of investigation are improved. Such has been the fortune of chemistry. Its first principles have been but lately ascertained: And it is already rich in corollaries, or general results, which embrace and combine all its parts. A systematic view of these results may be highly useful. During these last twelve years, I have constantly endeavoured to arrange them into some such form. I have often, in my courses of lectures, given a sketch of the arrangement I had adopted: More particularly, in those lectures, with which I every year close my course. When explaining the phenomena exhibited by the known elastic fluids in their evolution, their fixation, and their influence upon all the operations of Art and Nature; I take occasion to review the fundamental principles of the Science; and give such an abstract of its whole materials, as recalls to memory all the changes to which natural bodies are liable, under the power of their reciprocal attractions. But, in any attempt to combine together these capital truths, great perspicacity of discernment is requisite, to enable us to select those more general facts, in which all the minuter ones are so comprehended, that they may be deduced from them, as so many corollaries. Those more general facts must likewise be expressed with perspicuity and precision, without ambiguity, without doubt, without looseness of language. They must not be too numerous, but yet sufficiently so to include every general fact of any importance. They must also be arranged in such a consecutive series, and with a mu-

tual connexion so natural ; that they may exhibit all the elements of the science, and may shew their reciprocal relations and dependencies.

These ideas have regulated my investigation of those truths. I thought that they might serve for the foundations of a complete system of chemistry ; which should embrace such a number of principles, and those so happily applicable to every minuter phænomenon ; that it might enable persons already well acquainted with the science, to recollect all that immense multitude of facts of which it is composed ; and might, at the same time, explain to the beginner in chemical studies, the nature of the course on which he is entering.

It appeared to me, that I should best accomplish this purpose, by exhibiting a regular series of propositions, allied to one another by general relations, and so arranged, that their mutual connexion might be easily perceived. This I call *The PHILOSOPHY OF CHEMISTRY*. All the propositions contained in it, have been already printed under the article AXIOMS, in the chemical department of the New Encyclopædia. For the use of the student of chemistry, I have thought proper to publish them also apart, and in a commodious form.

The success of the first edition of *The PHILOSOPHY OF CHEMISTRY*, has encouraged me to reprint it. I have made a few alterations, and some small corrections, but hardly any addition. The nature of the work is such, that it can be little enlarged, until the science shall be greatly augmented, and enriched with important new discoveries.

PHILOSOPHY

PHILOSOPHY OF CHEMISTRY.

ALL the observations and experiments of Chemistry, may be reduced under the twelve following general heads.

- I. The action of *Light*.
- II. The action of *Caloric*.
- III. The action of *air in Combustion*.
- IV. The nature and action of *Water*.
- V. The nature and action of *Earths*; the formation of *Alkalis*; and the parts which these bodies act in combinations.
- VI. The nature and properties of *Combustible Bodies*.
- VII. The formation and decomposition of *Acids*.
- VIII. The union of *Acids* with *Earths* and *Alkalis*.
- IX. The oxidation and solution of *Metals*.
- X. The nature and formation of *Vegetable Substances*.
- XI. The transition of *Vegetables* into the state of *Animal Matters*; and the nature of *Animal Matters*.
- XII. Lastly, the spontaneous *decomposition of Vegetable and Animal Substances*.

THESE twelve articles may be made the titles of so many chapters; under each of which, may be introduced all such particulars as have a more natural and direct connexion with it, than with any of the others; and which shall all together comprehend the whole sum of our Chemical Knowledge.

CHAPTER I.

The ACTION of LIGHT.

I. **L**IGHT, whether it be emitted from the Sun and the Fixed Stars, or be naturally diffused through all material space, has four different modes of action in respect to the other bodies with which it comes into contact. It is either reflected wholly without decomposition from their surfaces, so as to give the sensation of *Whiteness*, when it meets the eye: Or it is decomposed, and but partially reflected, exhibiting any of all the variety of colours, except *White* and *Black*: Or it is more or less entirely absorbed, so as to afford to the eye, nothing but a *Black* shade: Or it passes through the bodies meeting it, with a greater or a smaller deviation from its former direction towards the perpendicular; which constitutes *Transparency*.

II. Passing through transparent bodies, it is refracted in the direct ratio of their density, if they be incombustible; and the refraction increases in the direct ratio of the increase of the combustibility of the body through which the light passes. Hence did Newton conjecture the combustibility of the diamond, and the existence of a combustible principle in water.

III. Light suffering refraction, is decomposed into seven different rays; red, orange, yellow, green, blue, indigo, and violet. It has been supposed, that three of these colours are simple; red, yellow, and blue; but the other four, compounded, each of those two which appear on each side, next to it in the refracted pencil of rays; orange, of red and yellow; green, of yellow and blue; indigo, of blue and violet; violet, of red and indigo. This opinion, however, has not been satis-

The

factorily proved. The decomposition of light by the prism, is a sort of analysis of it.

IV. Light acts likewise *chemically* upon bodies, in processes of combination and decomposition. Bodies immersed in light, differ in their character, from bodies kept remote from its contact; even when the other circumstances are equal. The former usually become coloured, volatile, and inflammable; the latter exhibit properties opposite to these.

V. By this chemical action of light, some acids are decomposed, and various other salts undergo a change of nature; metallic oxides are in general reduced nearly to the metallic state; vegetables acquire colour, sapidity, and inflammability. Plants withdrawn from the impulse of light, remain white and insipid; in consequence of which they are said to be *etiolated*.

VI. Light seems to produce these effects, almost solely by abstracting from bodies which have been burnt, that principle which they absorbed during the combustion; and by thus restoring to them that combustibility which they had lost. It may be said, that light *unburns* burnt bodies.

The foregoing propositions may be applied to explain

The colours of bodies;

Transparency;

Opacity;

Brilliancy;

Single or double refraction;

Metallic lustre;

The decomposition of acids and of metallic oxides;

Decomposition;

The alteration of mineral colours;

Vegetation;

The renovation of the vital air in the atmosphere;

The decomposition of water by the leaves of plants;

The formation of oils;

The differences of nature, which distinguish the vegetables of hot, from those of cold climates.

C H A P. II.

The ACTION of CALORIC.

I. THAT which mankind in general call *Heat*, is a *sensation* produced by a substance which modern chemists denominate *Caloric*. Caloric applied to the human body, in a proportion larger than that in which it already exists in it, warms our frame, and presents heat to our senses. When matters lower in temperature than our body, are applied to it, there is a portion of its caloric abstracted ; and we feel, of consequence, the sensation of cold.

II. Caloric penetrates through all the other substances in nature. It separates their component particles from one another, and makes room for itself among them. It diminishes their mutual attraction ; and dilates the bodies which they compose. It fuses solids ; and rarefies liquids to such degree that they become invisible, assume the form of air, and are thus converted into elastic, compressible, aeriform fluids. Liquids are therefore combinations of solids with caloric ; gasses are solutions of diverse bodies in caloric. Caloric is of itself, the most divided, the most attenuated, the lightest, and the most elastic of all the substances in Nature : And hence, its gravity cannot be estimated.

III. Caloric augments the mutual attractions of contiguous bodies, precisely in the same proportion in which it divides,
and

and diminishes the mutual attraction of the component particles of each of them. In consequence of this, it is successfully employed to effect new combinations ; and to promote the reciprocal union of different bodies. Hence the axiom *corpora non agunt, nisi soluta ; bodies act not on one another, unless previously dissolved.*

IV. Every different body, having a form and an arrangement of its constituent particles peculiar to itself, requires a peculiar quantity of caloric, to heat it to any given temperature : which is called its particular *capacity for containing caloric*. From this it follows, that different bodies, even when of the same temperature, and when indicating the same degree of the thermometer, really contain different quantities of caloric.

V. That particular quantity of caloric, which each different body requires, to communicate to it any given temperature, is called its *specific caloric*. And as the differences of this specific caloric in different bodies, cannot be measured by the thermometer ; there has been an *invention* produced, which measures the differences of specific caloric in different bodies of the same temperature, by ascertaining the quantity of ice, which each of these bodies melts, while falling from the same higher to the same lower degree of the thermometer. The differences of the quantities of melted ice, indicate the diversities of specific caloric in the different bodies thus compared. The instrument which this invention employs, is called a *Calorimeter*.

VI. All the experiments of those modern philosophers who have investigated the theory of caloric, concur to prove, that bodies, when they change their state, suffer also a change of their respective capacities for containing caloric. *By the change of the state of bodies*, is meant, the alteration of their solidity, liquidity, or elastic fluidity. By the mixture, therefore, of any two solid bodies, of unequal temperatures, and not entering into mutual combination, but having the same

capacity for containing caloric, we shall obtain a mass of an exactly intermediate temperature. But if these two bodies be of unequal capacities for containing caloric, then the temperature of the mixture will not be precisely intermediate between the temperatures of the two different bodies: And according as it recedes more or less from the precise intermedium, will the difference between the capacities of the two bodies be greater or less.

VII. The foregoing facts shew, that caloric has different attractions or degrees of affinity for different bodies. In all combinations, therefore, the varied attraction of caloric ought to be carefully observed, and estimated.

VIII. When bodies enter into mutual union, they either suffer a loss of caloric; which shews the new compound to have a smaller capacity than its constituent parts had, for containing caloric; and in which case, the process exhibits heat to our organs, and the temperature of the mixture rises; as is the most common effect: Or else the bodies entering into combination, absorb caloric; and the new compound contains more caloric, than its component parts contained when they were separate; in which case, the mixed substances cool, while the combination is taking place; the caloric which was before diffused in a free state among their component particles, is now more intimately combined with them; and there is even an absorption of caloric from contiguous bodies.

IX. Caloric sometimes adheres so tenaciously to particular bodies, as to hinder these from entering into combination with other bodies presented to them. There are various substances, which, when rarefied to the state of gaseous or elastic fluidity, neither unite with extraneous matters, nor with one another. Double affinities must be employed, if we wish to make them enter into new combinations, without having first changed their gaseous form.

X. So powerful is the attraction of caloric for certain bodies, that it is very often usefully employed to detach those bodies from compounds in which they are combined; and to analyse or decompose a variety of compound substances. In distillation, and in processes of decomposition, effected by the aid of fire, the whole process consists in the application of fire or caloric to matters of an extremely compound nature. These matters are thus gradually dissolved; and their principles are severally detached in a vaporous or gaseous form, and in the order of their solubility by caloric.

XI. It often happens, that light applied in conjunction with caloric, aids its operation, and *vice versa*. Chemists find it advantageous to use transparent vessels, which, when in the furnace, admit both light and caloric together. The effect is the same, when opaque vessels are sufficiently penetrated with caloric, to become red-hot, or permeable by light.

XII. Some bodies absorb caloric much more rapidly than others: And this property of absorbing caloric is termed rather *the conducting of caloric*. Those bodies which are the most highly coloured, are in general the best conductors of caloric. But the cause of this phenomenon is unknown.

XIII. All these facts agree in proving, that caloric is a peculiar substance; not, as some philosophers have supposed, a modification of all natural bodies. We know not, as yet, whether it be same with light. The farther we advance in the philosophical knowledge of Nature, the more differences do we still continue to discover between the action of the one of these bodies, and that of the other.

Application of the foregoing Axioms.

The Dilatation of solids; and the Rarefaction of fluids;
Thermometers;
Fusion;
Sublimation, and Volatilization;

The Calorimeter ; a table of the specific caloric in different bodies ;

The changes of temperature in different mixtures ;

Artificial refrigeration ;

The production, and the fixation of Gasses ;

Distillation, with different temperatures ;

Incandescence ;

The different conductors of Caloric ;

The attractions of Caloric.

C H A P.

C H A P. III.

The ACTION of AIR.

I. THE air acts in a mass, upon all the other bodies in Nature, by its weight, its dryness or moisture, its temperature, &c. Hence, processes of combination or decomposition to which air has free access, differ greatly from those performed *in vacuo*. And for this reason, it is always necessary, in chemical experiments, to pay careful attention to the indications of the barometer, the thermometer, and the hygrometer.

II. The atmosphere is a vast laboratory in which Nature continually performs numberless processes of analysis, solution, precipitation, and combination. It is an immense recipient, in which all the attenuated and volatilized products of terrestrial bodies, are received, agitated, mingled, combined, or separated. The air of the atmosphere may thus be regarded as a vague and confused mixture of mineral vapours, of minute particles of bodies animal and vegetable, of seminal grains and eggs ; through which the luminous, the caloric, and the electric fluids, incessantly pass and repass in all directions. Those great changes to which it is liable ; the operation of each of which, extends at once through a wide tract of space, and which are exhibited to our senses, in the
production

production of water, light, free caloric, and noise ; have received the name of *Meteors*.

III. Although of a composition so extremely mixed, and seemingly uncertain ; yet is the air of the atmosphere, to our perceptions, the same in its primary qualities, whatever the place from which the specimen is taken. Its particular character is distinguished by its two most eminent properties—of *maintaining combustion*, and *being fit for the salutary respiration* of animals. These two grand phænomena are so nearly allied to each other, that a distinct knowledge of the nature of air, may be obtained by the careful observation of what passes in the case of combustion.

IV. A combustible body will not burn, unless it be in contact with atmospheric air, or with a certain substance extracted from atmospheric air. Combustion cannot take place *in vacuo*.

V. In any given quantity of air, a combustible body can burn only for a certain proportionate space of time. An hundred parts of atmospheric air, contain only twenty-seven parts that can contribute to combustion. After a combustible body shall have absorbed these twenty-seven parts, the combustion will then stop ; because the remaining seventy-three parts can be of no use to promote it. Atmospheric air is a compound of two different substances ; having only some other extraneous matters mingled with it ; which do not exceed an hundredth part of the whole. Of those two component principles of atmospheric air, *one* serves for the purposes of combustion and respiration, and is called *Vital Air* ; the *other*, differing from vital air, in possessing qualities directly contrary to its two most eminent ones, is called *Gas Azote*.

VI. A body burning in common air, therefore, actually analyses this fluid ; detaches the vital air ; and by absorbing it, gains an increase of weight, and undergoes a change of nature. The gas azote that remains, is lighter than atmospheric air ; extinguishes combustion, and destroys animal life ;

life ; and is, as we shall hereafter see, a principle in the composition of many bodies, particularly of ammoniac or the volatile alkali, of the acid of nitre, and of animal substances.

VII. A combustible body, after being burnt in atmospheric air, and absorbing as much vital air, as it is capable of receiving into combination with it ; cannot again burn, although it be immersed in fresh air ; but has become combustible, and generally saline.

VIII. A body burning in atmospheric air, never entirely absorbs the ,27 parts of vital air. To detach the whole of the vital air, from any quantity of the air of the atmosphere, and thus to accomplish a complete analysis of the latter ; combustible bodies must be repeatedly immersed in it, and the combustion renewed for several different times in succession.

IX. That portion of air which is thus absorbed by combustible bodies, and which we have hitherto named *Vital Air*, is likewise denominated *Gas Oxigene*. It has received the *first* of these names, because it is the only elastic fluid fit for the salutary respiration of animals. The *second* has been affixed to it, because many bodies are, by the absorption of it, rendered acid.

X. Combustion consists, then, in the fixation and absorption of vital air by combustible bodies, and in the decomposition of atmospheric air by these bodies. Since no elastic fluid but vital air, can act the same part in combustion ; it is easy to conceive, that a body which is sufficiently combustible to absorb all the vital air out of a given quantity of atmospheric air ; may be employed as a means of ascertaining the precise proportions in which the two elastic fluids of the atmosphere are combined together in it. Phosphorus is, upon this principle, at present used as an *Eudiometer*, to indicate the purity of air, that is, to shew what proportion of vital air it contains.

XI. As vital air is a *Gas*, and many combustible bodies, by absorbing, fix it, and make it take a solid form ; it must necessarily happen, that vital air, when thus precipitated, will lose the caloric to which it owed its elastic fluidity. Hence comes that free caloric or heat, which is evolved during combustion.

XII. Combustible bodies differ from one another, 1. In the degrees of rapidity, with which they respectively absorb oxigene ; 2. In the quantities of oxigene which they respectively absorb ; 3. In the proportions of the caloric which they severally disengage from the oxigene absorbed ; 4. And consequently, in the more or less perfect solidity of the oxigene contained in them all, after combustion.

XIII. Burnt bodies may therefore be defined to be *bodies combined with oxigene*. They are called also, *oxigenated* or *oxidated substances*. And since the greater part of those bodies which are known to us, are either *burnt* or *combustible* ; there is reason for thinking, that a number of incombustible natural bodies, the composition of which is unknown, may possibly be hereafter found to be incombustible, only because they are already saturated with oxigene. In several instances, this conjecture has been already confirmed by the progress of chemical discovery.

XIV. From several of these preceding axioms, it follows, that when we burn a combustible body, that it may give us heat ; as, in our domestic apartments, in the cold of winter ; we derive, not from the combustible body, but from the air itself, the greater part at least, of the caloric which exists in combination with it. [It may even be asserted, that the colder the air, so much the more heat does its decomposition afford ; for the colder the air is, the more is it condensed ; and so much the greater is its quantity in proportion to its bulk. We know, that the heat of our common fires becomes much more lively and intense, when the surrounding air is suddenly cooled. The art, too, of increasing combustion by

I

pouring

pouring a stream of fresh air, with bellows, upon wood already inflamed, is founded upon this principle *.]

XV. Combustion, therefore, decomposes not only atmospheric air, by the absorption of one of its principles ; but also the vital air abstracted, by absorbing, fixing, and solidifying more or less, the *oxigene* or base of the vital air, in the combustible body ; and by disengaging in greater or smaller abundance, the *caloric* which was the solvent of that base.

XVI. Combustion exhibits another interesting phenomenon which has been explained by modern chemistry. This
is

* The Author seems here to misrepresent, or to express obscurely, the true chemical fact. *Cool air* is cold and dense, only for want of *caloric*, to rarefy and warm it. Before the *caloric* can escape, and the *oxigene* enter into combination with the *burning body* ; the *vital air* must ever be saturated with *caloric*, to that point at which the *attractions* of *oxigene* for the *combustible body*, and of *caloric* for other contiguous substances, are sufficient to overcome the mutual attraction by which *caloric* and *oxigene* are held in union, in *vital air*. Now, one combustible body may indeed have a more powerful attraction for *oxigene* than another ; *oxigene* may have absorbed *caloric* beyond the due point of saturation : And hence will the quantity of *caloric* vary, which is necessary to fit *vital air* for ordinary *combustion*. But this variation is never such as the author seems in the text to suppose. Cold air is always rarefied by the absorption of a new quantity of the surrounding free *caloric*, before it enters into combustion. A stream of dense, cold air, revives and inflames combustion,—solely by the more rapid *mechanical* expulsion of the freed *gas azote* ; by the absorption or expulsion of the evolved *caloric*, which would otherwise have floated about, so as to make the process languish ; and by a removal of the ashes, or the new compound of the combustible body and *oxigene*, in consequence of which, fresh parts of the combustible body, are exposed to the contact of the vital air. The action of *bellows* in promoting inflammation, is thus almost wholly mechanical.—In reading those sentences of the text which I have inclosed within brackets, it is to be carefully remembered, that, *cold air does not necessarily contain more caloric, than the same bulk of hot air may contain ; but only has a capacity of containing more ; which must commonly be more or less satisfied, before it can be decomposed by combustion.* H.

is the disengagement of light, or the production of flame. It is certain, that the greater part of the light which constitutes flame, is contained in vital air, of which it is a component principle : 1. Because combustible bodies yield much more flame, when they burn in vital air alone, than in atmospheric air : 2. Because some combustible bodies afford no flame, unless when burning in pure vital air : 3. Because, in order to abstract oxigene out of bodies containing it, for the formation of vital air ; it is necessary not only to dissolve the oxigene in a greater or smaller quantity of caloric, but also to add, at the same time, a due portion of light : 4. Lastly, Because there are burnt bodies, which, at the bare contact of light, are deprived of their oxigene. The last of these four facts is expressed by the terms, *unburning* and *decombustion* ; phenomena which were said, in the first chapter, to be produced by the action of light.

XVII. Vital air is therefore a compound of *oxigene* ; a solidifiable, ponderous, acidifying base ; held in solution by *caloric*, and *light* ; which are of themselves substances in a state of extreme attenuation, extremely elastic, and having no measurable gravity. Combustion consists in the more or less perfect precipitation of oxigene from its union with these its two solvents.

XVIII. A combustible body, then, when burning, disengages from vital air, not only caloric, but light also. Every different combustible body disengages its own peculiar portion, as well of light as of caloric, from vital air. There are probably some combustible bodies which disengage more of caloric than of light from vital air ; and others again which disengage from it more of light than of caloric.

XIX. Oxigene that is fixed in burnt combustible bodies, is therefore more or less entirely deprived of its light and caloric. The density, the solidity, which it then acquires, is one of the causes that regulate the more or less easy separation of oxigene from burnt, combustible bodies, for the formation of
new

new vital air. Some of these bodies require, in order to this, more of light than of caloric, while others take more of caloric than of light.

XX. From what is here said, it is easy to conceive, that the abstraction of oxigene from a burnt body, is a process directly the reverse of combustion. Our language wants a word to express this operation. It may be said to *unburn* or *de-oxidate* bodies: And hence we may derive *unburning* or *de-oxidation*, as names to denote the event accomplished.

XXI. Oxigene, beside adhering more or less tenaciously to combustible bodies, according as it is in its union with them, more or less solid, and has lost more or less of its solvents, caloric and light; is also attached to those bodies by virtue of its attractions, or peculiar affinities for every different one of them respectively. We are already acquainted with many of these affinities of oxigene, for different bodies: And of some of them, the precise forces even, have been correctly ascertained.

XXII. By means of these affinities, we often make oxigene to pass from a burnt, into a combustible body. A species of combustion then takes place, which is more or less tacit and secret, in proportion as the oxigene is more or less solid in its combination with the burnt body, and more or less in the same state of density, as the substance into which it is passing. But this species of combustion is sometimes accompanied with vivid flame and heat; phenomena which are exhibited, whenever the body which receives the oxigene, requires it in a state more solid than that in which it existed in the substance now divested of it. Thus iron, zinc, antimony, arsenic, &c. burn with flame, when heated in contact with oxide of mercury: They rob this oxide of its oxigene, and require the oxigene to become more solid, as it enters into combination with them.

The foregoing propositions may be applied to explain
The resistance which the air makes to evaporation, to the
ebullition of liquids, to sublimation, &c.;
The solution of water in air, and the variations of the
dryness and moisture of the atmosphere ;
The efflorescence and deliquescence of saline bodies ;
Aqueous meteors ;
Experiments made at different heights in the atmo-
sphere ;
Experiments made *in vacuo* ;
The comparative natures of combustible bodies ;
The increase of the weight, and the change of the nature
of these bodies after combustion ;
The history of native burnt bodies ;
Artificial flame and heat ;
The theory of furnaces ;
The different processes performed with *Eudiometers*, for
ascertaining the degree of the purity of air ;
The respiration of animals ;
The reduction of air to a mephitic by the effects of com-
bustion and respiration ;
The support, diminution, and augmentation of animal
heat ;
Transpiration from the skin and from the lungs, &c.

CHAP. IV.

The NATURE and ACTION of WATER.

I. **WATER** exists in three different states. It is *solid* in ice; it is best known as a *liquid*; it is expanded by rarefaction into *vapour* or *gas*.

II. Ice is a crystallization more or less regular, transparent, highly sapid, elastic; fusible at a temperature above 32° Fahrenheit; and which when entering into several new combinations, still gives out caloric, notwithstanding its previous apparent destitution of heat.

III. Ice of the temperature of 32° of Fahrenheit's thermometer, requires to its fusion, precisely that quantity of caloric which would be sufficient to raise an equal quantity of water to the temperature of 167° Fahrenheit. Its capacity for containing caloric, is therefore not precisely the same as that of liquid water: a difference owing to the peculiarity of the state of ice; as has been explained in the VI. Section of the II. Chapter.

IV. Whenever liquid water loses much of its heat, in entering into a new combination; it may be considered as becoming solid. In such combinations, it is often more solid than

ice at the temperature of 32° F. Hence the solidity of mortar, and other cements made with flaked lime.

V. Water remains eternally solid, on various mountains which have been for ages chilled by the presence of ice, as well as under the poles. It there forms a sort of rocks, or hard and white concretions, not unlike to stones.

VI. Liquid water is pure and tasteless, without smell, and 850 times as heavy as an equal bulk of air. It forms rivers, lakes, ponds, springs, brooks, &c. It occupies cavities, furrows, and in general all the lowest parts of the surface of the globe.

VII. It is rarely pure. At the surface, and in the interior parts of the earth, it dissolves and retains air, saline gasses, and terrene salts. It even acts upon the most solid stones, wears them down by attrition, deposits the particles which it carries with it, and forms them into crystallized figures. It has been, on this account, named the great solvent of nature. It gives rise to many phænomena; and is one of the prime agents which are for ever modifying anew the surface of the globe. Its motions, its currents, its action, have at length changed the nature of minerals, and have created, as it were, a sort of new world, upon the old.

VIII. All waters on the earth contain, therefore, some extraneous substances. The presence of these may be recognized by the extraordinary specific gravity of the water; by its taste being more or less insipid, earthy, and crude; by its aversion to boil, and its inability to soften pulse, or to froth soap. That water is the most pure, which is the farthest from possessing these qualities.

IX. Water, running over a bed of quartzose sand, and in contact with air, is sufficiently pure for the ordinary purposes of life, and of the arts. But, water which passes through chalk, plaster, or marble, or which stagnates over *peat-earth*, bitumen, mineral ores, or in subterraneous caverns, at a distance

distance from the action of the atmosphere ; is always more or less impure.

X. Chemistry corrects the impurity, crudeness, and hardness of waters, by exposing them to the air, agitating them in contact with it, by boiling, distilling, and then *aerating* them. The addition of ashes, alkalis, and light acids, serves to remove in part, the bad qualities of water, and sometimes even destroys those qualities altogether. Most of those extraneous bodies by which the purity of water is altered, being either much more volatile, or much more fixed in their nature than water; distillation is therefore the surest means for purifying water. Chemists, for this reason, use always distilled water in their experiments.

XI. As liquid water is a combination of ice of the temperature 32° F. with such a portion of caloric as would be sufficient to raise a quantity of water equal to the quantity of ice employed, to the temperature of 167° F.; therefore caloric added to liquid water, rarefies it. At 212° F. water takes a gaseous form, and is diffused in vapour. This vapour is much lighter, and in proportion to its actual weight, is expanded into a much greater bulk, than liquid water. It easily penetrates through all other bodies; and is dissolved in air. The elastic efforts which it makes to expand itself, whenever it experiences an increase of temperature, fit it for moving the largest bodies.

XII. As liquid water absorbs air, and thus becomes lighter; so air also absorbs and dissolves water. Hence the evaporation of water. This solution of water in air is dry and invisible, like the air; it follows the ratio of the temperature of the atmosphere. The hygrometer does not accurately indicate the presence of water in this state; for a perfect solution of water in air, does not at all affect that instrument. But water about to be dissolved in air, and still more water precipitated from this solution, never fail to alter the indications of the hygrometer.

XIII. Water is not, as it was long supposed to be, a simple body. Upon the rapid combustion of various combustible bodies, more or less intensely heated; such as charcoal and pitcoal both previously kindled; iron red-hot, zinc in fusion and red-hot, oils, &c.; water presented to these bodies in this state, undergoes a decomposition; and a quantity of oxigene derived from it, is fixed in the combustible bodies.

XIV. While the *oxigene* from water is *fixed* in those combustible bodies which it kindles and inflames; the other component principle of the water, being susceptible of solution in caloric, forms *inflammable gas*, which is diffused in an uncombined state. This second substance, as being one of the elementary principles of water, has been named *hydrogene*; and its elastic fluid solution in caloric and light, has been called *gas hydrogene*. That disengagement of this substance into gas, which takes place whenever water is decomposed by a combustible body, is the cause of a great number of detonations and fulminations.

XV. The gas hydrogen obtained in very many chemical processes, comes always from water; *either* radically, and by the effect of a former decomposition, by which the hydrogen has been abstracted from water, and fixed in some other body which now resigns it; *or* by the immediate and instantaneous decomposition of water itself.

XVI. It has been ascertained by many experiments, that water contains about 0,85 of oxigene, and 0,15 of hydrogen. The composition of water by a chemical process; one of the noblest discoveries of modern chemistry; confirms the certainty of the analysis of water. For, 0,85 parts of oxigene, added to 0,15 of hydrogen, give 1,00 parts of pure water.

XVII. The decomposition of water by a combustible body, is always effected by the double affinities—of the oxigene of the water for the combustible body, and of caloric for the hydrogen of the water. On this account, the greater the quan-

tity of the caloric matter employed ; so much the more rapid is always the decomposition of water by iron, charcoal, &c. From this need of a great abundance of caloric, in this process, an idea may be drawn, of the manner in which hydrogen, one of the component principles of water, comes to acquire a degree of levity so much greater than that of the water in which it before existed : A cubic foot of water weighing 70 lib.; while a cubic foot of gas hydrogen, weighs only 61 grains.

XVIII. Gas hydrogen, which is always *originally* derived from the decomposition of water ; carries with it, usually a considerable portion of the body with which it was last combined ; and this either in suspension or solution, according as that body was of a nature more or less mixed. It is commonly mixed with gas azote, with carbonic acid gas, or with vital air ; or it holds in solution, water, carbone, sulphur, phosphorus, arsenic, oils, alcohol, æther, &c. According as its purity is contaminated by one or another of these different substances ; it varies in odour, gravity, inflammability, the colour of its flame, its action upon different substances, and the extraneous products which, beside pure water, it affords, when burnt. Hence all the different species and names of inflammable gas, the generic base of which, is always gas hydrogen.

XIX. Gas hydrogen being one of those natural substances which contain the most caloric ; is one of those combustible bodies which the most easily suffer their caloric to escape ; and which, by consequence, afford the most heat, when burning. Hence, all compound, inflammable matters ; such as oil, grease, and in general all those which are obtained from organized bodies ; having hydrogen for one of the most abundant principles in their composition ; yield much heat, during their combustion. Of this character, are also timber, oils, pit-coal, bitumen, alcohol, æther, &c.

XX. It follows also from the preceding facts, that compound, combustible bodies, containing much hydrogen in their composition; must require, when they burn, a very large proportion of oxygen, and will afford water, as a product of their combustion, in just proportion to the quantity of hydrogen which they contain. Thus a pound of alcohol gives by combustion, more than a pound of water, &c.

XXI. The combustible bodies that decompose water, are in general, those which have a stronger attraction for oxygen than hydrogen has. But the efficacy of this attraction is greatly aided by the presence of caloric, which for its part tends to combine with hydrogen. Great abundance of caloric, may even render water decomposable by bodies, which, if cold, would be unable to decompose it. Light also contributes to the same effect.

XXII. Combustible bodies which, at whatever temperature, do not decompose water, on account of the faintness of their attraction for oxygen; which is in this case always weaker than the attraction between oxygen and hydrogen;—will, on the contrary, after being burnt by other means, undergo decomposition by suffering hydrogen to abstract the oxygen which they had acquired, when burning. This happens to the oxides of lead, bismuth, &c.

XXIII. Chemistry knows, as yet, no other means of decomposing water, but by presenting to it, combustible substances capable of detaching and absorbing its oxygen. We are acquainted with no bodies that we can apply in art, to absorb the hydrogen, and leave the oxygen disengaged. Nature however, possesses instruments by which she can accomplish this particular decomposition of water. The leaves of vegetables, when the rays of the sun fall upon them, seem to decompose water, to absorb its hydrogen, and to evolve its oxygen into vital air. This appears to be, in part, the mechanism

aim of vegetation, of the formation of oils, and of the renovation of the atmosphere. See Chap. IX.

XXIV. While hydrogen and oxygen, dissolved each into into gas by the efficiency of caloric and light; remain both cold; they cannot combine, although brought into mutual contact: no inflammation is produced by their mutual impasse; there is no water formed. But when a burning body is presented to the mixture, when it is powerfully compressed, or if it receive any sudden and violent shock: the two gases then begin to unite; combustion ensues; and water is produced.

XXV. It should seem, that a like event happens in the atmosphere. Detonations in the air, or claps of thunder, are probably nothing else but the combustion of hydrogenous gas with vital air; and are accordingly followed, for the most part, by heavy showers of rain. Other tempestuous rains appear also to be owing to the sudden formation of water in the atmosphere; in consequence of the rapid combustion of hydrogenous gas and vital air; occasioned by the electric spark, and by the necessity for restoring the electric equilibrium between one cloud and another, or between the clouds and the earth.

XXVI. A multitude of chemical phenomena in nature and art, that seemed formerly to be unaccountable and miraculous; are now perceived to be necessary consequences of the decomposition of water. The influence of the general facts enumerated in this chapter, is very great, upon the whole theory of chemistry. They will recur to our notice in all the subsequent chapters.

Application of the preceding propositions.

Artificial refrigeration;

Theory of icy mountains, and of the polar ices;

Varieties of the waters of the earth and atmosphere;

Art of correcting the bad qualities of water;

Theory

Theory of the ebullition of water ;
Difference between boiled and aerated water ;
Distillation of water in large quantities ;—of salt water ;
Theory of mists and dews ;
Theory of the hygrometer ; and of the phænomena mea-
fured by it ;
Inflammation of combustible bodies by water ;
Gasses disengaged from the waters of marshes ;
The diversity of inflammable gasses ;
Colouring by inflammable gasses ;
The oxidation of metals, or rust formed by moist air ;
Theory of detonation ;
Some of the phænomena of the solution of metals ;
Some fundamental principles towards a theory of vegeta-
tion, of the formation of oils, &c.

C H A P. V.

The Nature and Action of EARTHS and ALKALIS.

I. WHAT was formerly meant exclusively by the name of *Earth*; and was supposed to be an *elementary* substance, the cause of solidity, dryness, insipidity, insolubility, &c.; is no longer to be regarded in any other light, than as one of those vague, indeterminate ideas, which the imagination dissatisfied with the fruitlessness of experiments, often frames to amuse it, instead of facts. We now acknowledge no such thing as *elementary* earth. Instead of one, we have attained to the knowledge of five terrene substances; each of which has an equal right to be termed *elementary*, since each of them is found to enter into very many compounds.

II. Of the five simple terrene substances which have been discovered, there are two in some sort more eminently earthy than the rest, more dry, more susceptible of hardness, more insipid, &c. The other three possess saline qualities which give them a similarity of nature, to alkaline substances. These last three have been therefore denominated *Salino-terrene*, *saline earths*, *alkaline earths*, *terrene alkalis*. The two first are *silices* and *aluminas*. The latter three are *barytes*, *magnesia*, and *lime*.

III. Each of these five earths, is distinguished by *specific* characters, beside those *generic* qualities which belong to all the five, in common. Their generic characters are, dryness, unalterability by fire, the property of not being liable to decomposition, and of acting, in combinations, as simple, indestructible substances.

IV. *Silices*, has been named also *siliceous earth*, *quartzose earth*, *vitriifiable earth*. It is rough to the feeling of the hand: it scratches and wears down metals; it is infusible, and incombustible; insoluble in water or acids—at least the greater number of acids; it is soluble by alkalis, when exposed in contact with them, to an intense heat, and in consequence of this solution, forms with them a glass. This simple earth is found in great abundance, in sand, quartz, flint, agate, jasper, grit, and in all scintillating stones, which, indeed, have it for their bases. It has not, as yet, been either decomposed, or imitated by synthesis. It has been considered as the simplest of all earths, the element of earth, the principle of every other sort of earth: but these opinions have not hitherto been justified by observation or experiment. It is applied to a multiplicity of uses, for mill-stones, the manufacture of glass, cements, pottery, &c.

V. *Alumines*, so named, because it forms the basis of alum, is called also *Argill*, by some writers. It is soft to the finger, adheres to the tongue, forms a paste with water, hardens in the fire. It combines with most acids, dries into flakes, and assumes extraordinary hardness when mixed with water and *silices* together. It is contained in a large proportion, in common clays, in pipe-earth, in schistus, steatites, &c. In many of the arts it is employed, as a substance adapted to receive and retain any artificial form, which may be baked by the fire, and which is fit to resist the penetration of water. Its intimate nature or component principles are unknown; it has been erroneously regarded, as *silices* altered, divided, and mouldered down by the action of air and water.

VI. Barytes, or *ponderous earth*, is a substance remarkable for its extraordinary gravity. In nature, it is never found alone, but always in combination with the sulphuric or the carbonic acid. It takes a green or blue colour, when exposed to the action of fire, in contact with the filices, or aluminés of the crucible. In nine hundred parts of water, it dissolves; it communicates a green colour to the syrup of violets; it has a greater affinity than even the alkalis with most of the acids; its origin is unknown; but it is suspected to be a metallic oxide; it serves, at all times, to detect the presence, and ascertain the quantity of the sulphuric acid.

VII. Magnesia is a substance very fine and white; not subject to alteration by fire; soft and light; it resembles the feculum of vegetables, and requires nearly two thousand parts of water to dissolve it. It communicates but a faint greenness to the tincture of violets and mallows; with acids, it forms salts which are very soluble, and in which the magnesia is combined with a force of attraction so much less than that with which lime adheres to acids, that they are all liable to be decomposed by lime. The attraction of magnesia for the acids, is nearly the same as that of ammoniac; accordingly ammoniac and magnesia entering together into combination with acids, thus form a class of triple-salts, or salts with two bases. This earth exists in a sufficiently perceptible proportion, in serpentines, mica, slate, amianthus. Like the preceding earths, it is indecomposable, and of unknown composition.

VIII. Lime, the most alkaline of all the earths, is the only one that has an acrid taste, hot, almost caustic, disagreeable, and urinous. It gives a dark-green tinge to syrup of violets, and when slaked in the open air, attracts moisture from the atmosphere. Under the action of water, it becomes exceedingly hot, and absorbing the water, becomes solid, in combination with it. When slaked barely by exposure to the atmosphere,

mosphere, it gives out caloric, largely : it is soluble in less than seven hundred times its own weight of water. Dissolved, it attracts carbonic acid from the atmosphere ; and on the surface of the solution, forms a pellicle of chalk which has been improperly termed *Cream of Lime*. Alone, it is unalterable by fire ; but with silices and aluminæ, is reducible to fusion. It is plainly a compound ; but its component principles are unknown.

IX. That earths are occasionally converted into one another, is merely a vain dream of naturalists. We have no proofs, that silices is by long exposure to the air, changed into aluminæ ; that flints are transformed into chalk ; that chalk is converted into magnesia ; as has been too hastily inferred from some slight and casual appearances.

X. The three alkaline earths have more the appearance of being compound, than magnesia or lime. We have reason to believe, that azote is one of their component principles ; and that they owe to it their alkaline properties. Yet this opinion has not hitherto, been sufficiently confirmed by experiments. The formation of the alkalis, is, indeed, with great probability, ascribed to marine animals ; and the fact that these contain much azote, seems to suggest, that azote is the grand alkaligenous principle in Nature.

XI. It has been supposed, that the five earths are of a metallic nature ; and it has been pretended, that by violent ignition with charcoal, their reduction into the metallic state, has been effected. But those very few, and very small metallic globules which have been in such instances obtained, came evidently from the charcoal, and from the earth of the cupels : and those having been discovered to be phosphure of iron, whatever the earth in the treatment of which they were procured ; it is hence evinced, that the earths afford no metallic matters. Some philosophers indeed continue to regard the earths, as a species of burnt bodies, in which oxigene is extraordinarily adhesive ; and which, on account of this adhesion,

fusion, cannot be decomposed. But, this opinion is, as yet, unconfirmed by observation or experiment.

XII. Earths combine with one another; two and two, three and three, and even in compositions more complex; by processes unknown to us, but which Nature continually accomplishes in the great way; by them, producing stones various in hardness, structure, transparency, opacity, colour, form, &c. Art cannot imitate these compounds, for want of time, of sufficient masses of the materials, and of an adequate extent of space. Yet it produces something similar to the natural compounds of the earths, by preserving long in mutual contact, mixtures of the earths, which have been well wrought together, and at the first, moistened with a little water.

XIII. The three alkaline earths hold an intermediate place between the earths and the alkalis; and are allied alike to both. The alkalis are known by their acrid, burning, urinous taste, their causticity, their peculiar action on the skin and all other animal matters, their converting the blue colour of violets to a green or even a greenish yellow, and their deliquescency. The known species of alkali, are three, potash, soda, and ammoniac. Of these, the two former are named *fixed alkalis*; because they melt and become red in the fire, before being volatilized: the third, as being in this respect, of an opposite nature, is termed *volatile alkali*.

XIV. Potash is known by the following characteristics. It is dry, solid, white, crystallized in rhomboidal plates, fusible at the temperature of 235° , extremely deliquescent; it absorbs water with the evolution of heat, and a peculiar, faint odour; by fusion, it combines very well, and forms a transparent compound with silices. In nature, it is often found with lime, and in combination with different acids. It is obtained more especially from vegetables; in the ashes of which it remains, after their combustion. It has been thought to have such a resemblance to lime, that it might possibly be formed by the combination

combination of that substance with azote. But this opinion is unconfirmed by experiment.

XV. Soda is obtained by the incineration of marine plants, and forms also the basis of common sea-salt. It has a remarkable resemblance to potash in its form, causticity, fusibility, deliquescency, its fusion with silices, its action upon animal matters, &c. It long was, and still might be confounded with potash. But the neutral salts which potash forms in combination with acids, are entirely different from those which soda forms with the same acids. Soda has been supposed to be a compound of magnesia with azote; because salts with a base of magnesia, are as often found together with salts which have soda for their base, as calcareous salts, with such as have for their base, potash. But neither the one idea nor the other, is well founded.

XVI. Ammoniac or *volatile alkali*, differs greatly from the two preceding species. Its form is gaseous and peculiar, when it is dissolved in caloric; dissolved in water, it has a liquid form equally peculiar; its odour is lively and suffocating; it is soluble in the air; it is known to be easily decomposable by the electric spark, by metallic oxides, and by the nitric, or the oxygenated muriatic acid. This decomposition has shewn ammoniac to be a compound of hydrogen with azote; and in consequence of this circumstance, it often exhibits the phenomena of a combustible substance. This also explains the reason why animal matters under putrefaction, give out ammoniac.

XVII. Should azote hereafter be ascertained to be the principle to which alkalis owe their formation; the atmosphere will then appear to be a compound of *oxigene* and *alkaligene* each dissolved, separately, in caloric. It will appear to be a vast reservoir, out of which the philosopher may behold nature drawing the materials of the two classes of compound agents which are the most active, and the most useful, in very many of her operations.

Application of the Propositions in this Chapter.

The extraction, the preparation, and the purification of earths.

The theory of the arts of making earthen-ware, bricks, tiles, pottery, porcelain ;

The theory of cements and mortars ;

The reciprocal combinations of earths by fire ;

The natural history of earths and stones ;

The compound nature of earths and stones ;

The natural alterations of stones ;

The changes of colours by the alkalis ;

Vitrification, and the processes of the glass-maker ;

The extraction and purification of potash and soda ;

The theory of alkaline caustics ;

Some particulars relative to putrefaction.

C H A P. VI.

The Nature of COMBUSTIBLE BODIES.

I. COMBUSTIBLE bodies are too numerous, various, and important in the phænomena which they present, and the combinations with one another and with air, into which they continually enter ; not to deserve to be examined with the utmost care, in order to the discovery of their different properties and specific characters.

II. Comprehending under this denomination, all substances that are capable of entering, more or less rapidly into union with oxigene, and of disengaging from vital air, its light and caloric : We must next distinguish those substances into two classes ; simple or undecomposed, combustible bodies ; and those combustible matters which are, in their nature, more or less compound.

III. We call those combustible substances, simple, which chemistry has not hitherto been able either to decompose, or to form synthetically. Their intimate nature is unknown. They are found sometimes solitary, in the mineral kingdom, or in the two other kingdoms of nature ; but almost always combined two and two together. Of this character are diamond, hydrogen, sulphur, phosphorus, carbone, and all metals.

tals. Each of these six genera, is worthy of being examined by itself.

IV. *Diamond* is the hardest of all bodies. It is very remarkable for the force with which it refracts and decomposes light; and from which NEWTON inferred, that it was highly combustible. In nature, it exists crystallized in octohædra, duodecahædra, &c. It has some varieties of contexture, density, and colour. It burns with a perceptible flame; and while it burns, is reduced to vapour. Its combination with oxigene is still unknown. Few bodies act upon it; were it not for its combustibility, it might be supposed absolutely unalterable. We know of no compound bodies into which it enters, as a component principle: of all the bodies in nature, it seems to be the least subject to chemical attraction.

V. *Hydrogene* is one of the component principles of water; and in combination with caloric and light, forms gas hydrogene. The weight of this gas is to that of atmospheric air, as *one* to *sixteen*. It is insoluble in most other substances; but, on the contrary, dissolves sulphur, phosphorus, carbone, arsenic, oils, &c.; and by these solutions forms various sorts of inflammable gas; which are at present named *sulphurated, phosphorated, carbonated, arseniated, oleaginous, &c. hydrogenous gas*. It decomposes several metallic oxides, and some acids, of which the *radical* principles are simple and well-known. To all its compounds, whether combustible or incombustible, it communicates a considerable refringent power. Because water possessed this power of refraction, NEWTON skilfully conjectured, that it must contain some such combustible substance, as this which has been at last discovered in its composition. Hydrogene is also fixed in organic bodies, and forms a principle of those mixed, combustible matters which they contain. See Chapters IV. and X.

VI. *Sulphur* is a yellowish substance, odorate, electric, transparent, and octohædral, opaque, and prismatic, fusible, and

subject to two different sorts of combustion. Of these combustions, one is slow, with a bluish flame, and yields sulphurous acid; the other is rapid, with a white flame, and produces sulphuric acid. Sulphur enters into combination with earths and alkalis; and by these combinations is rendered soluble. It unites with metals, and forms with them sulphurous ores, which exist in great abundance, in the earth, and either in a solitary state, or in combination with pure metals.

VII. *Phosphorus* is a white substance, transparent, crystallized, lamellated, and very fusible. It is subject to two different sorts of combustion; burning, either slowly, at any known temperature, with a whitish flame, an acrid odour, and the formation of phosphorous gas; or at the temperature of 167° , rapidly, with a vivid and very brilliant flame, without any sensible smell, and with the formation of phosphoric acid. On account of its extreme combustibility, it is never found pure, in nature. It enters with sufficient readiness, into combination with sulphur, and metals. It dissolves in gas hydrogen; detaches the oxigene from various metallic oxides; separates the metals from the acids, in the perfection of their metallic form and lustre. It exists in minerals, even more abundantly than in animals, to which it was formerly supposed to be peculiar.

VIII. *Carbone*, the combustible matter of coals, when pure from earth, alkali, salts, &c. may be burnt, if subjected to an intense heat. With oxigene, it forms carbonic acid. Of all known substances, it has the strongest attractions for oxigene; which it detaches from all other burnt bodies. It exists in a large proportion, in both animal and vegetable matters of all sorts. Of vegetables, it is almost the only solid base; and on this account, still remains in their form, after they have been decomposed, either spontaneously, or by the action of caloric. It dissolves in the alkalis, and in gas hydrogen. It unites with metals; forming, particularly, with

with iron, carbure of iron; which is found in all the kingdoms of nature, and has been improperly termed *Lead-ore*, *Plumbago*, and *Black-lead*.

IX. The metals are well known by their ponderosity and brilliancy. They are fusible, crystallizable, combustible. They decompose water and various acids, combine with sulphur, phosphorus, carbone, and with one another, at different temperatures. In the state of oxides, they act in respect to the earths and alkalis, the part of acids; and again serve to the acids, as so many salifiable bases. This genus differs from the preceding genera, in possessing many species. In order to give a short account of these species, of which there are now seventeen, well known,—a number which will probably be much enlarged by future investigation; I shall divide this *Genus* into five *Sections*. In the first section I shall comprehend metals brittle and acidifiable; which are three species; arsenic, tungsten, and molybdena. To the second section, I refer metals that are brittle, and oxidable only; being five species; cobalt, bismuth, nickel, manganese, and antimony. The third section will include two species of metals which are semi-ductile and oxidable; zinc and mercury. To the fourth section belong metals which are highly ductile, and easily oxidable; such as tin, lead, iron, and copper. Lastly, To the fifth section remain those metals which are highly ductile, but not easily oxidable; and these are the three species of silver, gold, and platina. As the *ninth chapter* is entirely appropriated to the purpose of explaining the most important chemical properties of metals, it will be sufficient here to mention briefly, some of the specific differences by which these bodies are distinguished from one another. It may be proper to observe, that the names of *semi-metals*, *imperfect metals*, *perfect metals*, having been, evidently, derived from the errors of alchemy, ought to be banished from the language of a science that has now attained to considerable accuracy.

A. *Arsenic* appears in plates of a bluish grey colour, brilliant, brittle, and which burn with a blue flame, and with the exhalation of a smell of garlic.

B. *Tungsten* is of a greyish white colour, granulated, friable, almost infusible, almost insoluble in acids, but very easily oxidable and acidifiable by air and caloric.

C. *Molybdena* presents itself in a powder, or in blackish grains which are brilliant, agglutinated, brittle, scarcely fusible, and which burn into a white oxide, that is volatile, prismatic, and acidifiable.

D. *Cobalt* is granulated, fine, of a rose-white colour, brittle and pulverizable, not easily fusible, and becomes blue, when it is melted with glass.

E. *Bismuth* appears in large plates of a yellowish white colour, brittle, very fusible, very crystallizable, very oxidable.

F. *Nickel* is grey, granulated, hard, not brittle, scarcely fusible, and yields a green oxide, under the action of caloric and air.

G. *Manganese* is of a greyish white colour, fine-grained, brittle; not fusible without great difficulty; the only metal combustible in the open air, and which instantly changes its colour, and is, within a few days reduced to a black powder. To preserve manganese from this spontaneous combustion, it must be kept in alcohol, or oil.

H. *Antimony* is white, pure, with large plates, brittle, difficult to melt; yields by combustion in the open air, a white oxide, which is sublimated and crystallized; and which combines with the alkalis in the same manner as an acid.

I. *Zinc* is of a bluish white colour, in large plates, semi-brittle, not without some degree of malleability, easily fusible, the most inflammable of all metals; when red-hot, it burns with a beautiful, yellowish white flame; it decomposes water with great energy.

K. *Mercury* is fusible at the temperature of $35\frac{1}{2}^{\circ}$ below zero in Fahrenheit's thermometer; and at 38° under zero, congeals. It may be reduced to a black oxide (*atbiops per se*) by mere division; and this simple process extinguishes and fixes it in all those thick or viscid matters with which it is usually triturated.

L. *Tin* is a glittering white substance, soft, light, scarcely sonorous, susceptible of being scratched by the nail, very fusible, very combustible; which yields a white oxide that impairs the transparency of glass, and converts it into enamel.

M. *Lead* is bluish, dusky, soft, heavy, easily fusible. It yields an oxide, more vitrifiable than the oxide of any other metal, and a glass of a topaz-yellow colour.

N. *Iron* is white, fibrous, the most tenacious of all metals, very averse from fusion, very combustible, the only metal attractable by the magnet. It acts with great efficacy in decomposing water; is reduced to a powder, by exposure to the open air; combines with charcoal, which converts it into steel; and is the only metal that abounds in the two organic kingdoms of nature.

O. *Copper* is of a beautiful, glittering red colour. It is very soft, very ductile, odorate, poisonous. It burns with a green flame: its oxides are brown, blue, and green. The green oxide requires humid air to its formation.

P. *Silver* is white, pure, and brilliant, without smell and without taste, highly ductile, not oxidable by caloric and air. It burns with a greenish flame, when acted upon by the electric spark. The vapours of sulphur, blacken it. By the action of air alone, it is unalterable.

Q. *Gold* is of a beautiful, glittering yellow colour, highly ductile, less combustible and oxidable than silver, less alterable than silver by the contact of air. The electric spark reduces it to an oxide of a beautiful purple colour.

R. Platina is the heaviest of all metals, of a greyish white colour, with little brilliancy; the most infusible, the least combustible, the least alterable of all metals. It may hereafter become one of the most valuable instruments of the arts.

X. Compound combustible bodies are such as result from the mutual combination of two or more of the foregoing simple combustible substances. The solutions of sulphur, carbone, phosphorus, arsenic, in gas hydrogene; are inflammable compounds. The combinations of sulphur with phosphorus; of carbone with iron; of metals with sulphur, with phosphorus, or with one another; are so many compound combustible bodies. These are the combustible matters, the most common in nature. Art separating them from one another, obtains them pure and solitary.

XI. A comparison of the properties of compound combustible bodies with those of the simple, shews that the former sometimes absorb oxigene more eagerly than their component principles would do if separate; as in the instances of many alloys and metallic sulphures: but that, on the other hand, some compound combustible matters are rendered more averse from burning than their principles disunited would be, by means of that strong energy of attraction which these principles exert one upon another; as is the case with all phosphorated metals in general. Some of these combustible compounds remain long unalterable in the air; seem to have in some manner lost their combustibility, by their mutual combination; and are at last kindled, only by the application of a strong heat to them: Of this character is carbure of iron, which has been usefully employed to preserve iron from rusting.

XII. Hydrogene and carbone are united in the most intimate manner in the capillary tubes of vegetables. They often contain in their combination, small portions of earth, alkalis,

kalis, and acids, but especially of oxigene. They form bitumens, oils, and resins; which, although tending to combustion, and a separation of their principles; yet remain for some time in the equilibrium of combination; until a sudden rise of temperature, and the contact of air or water, destroy the equilibrium, divide the elements of the compound, and bring them separately into union with oxigene. The products of the combustion of those compounds, are always, water and carbonic acid. The same thing takes place in the case of alcohol and æther, which are formed by modifications of the principles of vegetables, and which, in an ultimate analysis, are found to be merely combinations of hydrogen and carbone, with more or less of oxigene and water. See Chapters X. XI. and XII.

XIII. This short view of the different species of combustible substances, and of their principal characteristic properties, shews what an important part these bodies act in the phenomena of nature. It authorises us to divide almost all natural products into two great classes; *combustible* bodies, and *burnt* bodies. In the magnitude and the action of the former class, we see the cause of inflammable meteors, partial heats, volcanoes, perpetual changes of the surface of the earth, &c. In the existence of the second class, we perceive the source of the varieties and number of the acids, of the compound salts, of oxides and metallic salts, which diversify in a thousand ways the aspect of ores in the earth; the reciprocal decompositions of these substances; and the alterations they undergo from water, air, and light. Vegetables appear to be so many machines organized by nature, in order to accomplish the intimate mutual combination of many of these combustible substances; and thus to produce compounds, the unpermanency of which, makes them peculiarly serviceable to the grand designs of nature.

Application

Application of the foregoing propositions.

The history of the combustion of every different combustible body, in particular detail.

The history of sulphurated soils, and of native sulphuric acid.

The phænomena of natural inflammable gasses in quarries, mines, the atmosphere, &c.

The properties of terrene, alkaline, and metallic sulphures.

The conversion of sulphures into sulphates and sulphites, by the action of air and water.

The properties, extraction, and combinations of phosphorus; metallic phosphures.

The existence of metallic carbures in nature.

The phænomena which respect the density, the gravity, the ductility, and the fusibility of metals.

The properties and uses of alloys.

The formation of secondary ores; by transition from native metallic salts.

Volcanoes; sulphureous and bath waters.

Bitumens; the comparison of sulphur, charcoal, and other simple combustible bodies, with oils, &c.

C H A P. VII.

The FORMATION and DECOMPOSITION of ACIDS.

I. ALL acids resemble one another in taste ; in their manner of giving a red colour to vegetable substances ; in their common tendency to combine with earths, alkalis, and metallic oxides ; and in the property of attracting and being highly attractable. It was therefore natural to conclude, as did Sir I. Newton, that they resembled one another also in their intimate essence, and possessed some homogeneous principle common to them all. This truth, chemical analysis, with the assistance of the new inventions in chemistry, has ascertained beyond a doubt.

II. Since every acid contains oxigene, and loses its acidity, in proportion as it is deprived of this principle : Acids are therefore to be regarded as burnt or oxigenated bodies, which resemble one another by containing, all, more or less of the same acidifying element.

III. The nature of acids, may be examined in two ways ; either by producing them from their elements by combustion, uniting oxigene with substances liable to be acidified by it ; or by decomposing, and *unburning* acidified bodies, so as to detect

tach the oxigene, by means of other substances having a stronger affinity with it.

IV. Considered in this last point of view, all known acids may be arranged in three classes; 1. Acids which we can both compose and decompose, and with the nature of which we are fully acquainted: 2. Acids which we can compose, but not decompose, and with the nature of which we are, by consequence, more imperfectly acquainted: 3. Acids which have not been, as yet, either composed or decomposed, and of which the nature is, by consequence, wholly unknown to us.

V. Of nearly thirty species of known acids, there are, strictly speaking, only three, of the intimate nature of which we are entirely ignorant, as having been hitherto unable either to compose or decompose them. We may, therefore, regard the character of acids in general, as being well ascertained; and may proceed to consider them in their general properties, and with respect to their composition.

VI. All acids are, then, compounds of *oxigene* with *some other body*: The *former* principle, common to them all, being the cause of their general resemblance, and of those qualities in which they all agree; while the *latter*, which is different in every different acid, presents itself as the source of those specific qualities which are peculiar in each. The peculiar materials combined with oxigene in the various acids, are, on this account, called the *radical* or acidifiable principles.

VII. The acids are, then, all combinations, of the *radical* or acidifiable principle peculiar to each species, with oxigene, a principle common to all the species. Hence it follows, that their common properties, which give them the acid character, depend on oxigene; and that their mutually distinguishing qualities, which mark their specific characters, are owing to their radical principles.

VIII. The term *Acid* denoting the essential, general nature of these substances, forms the generic name. The peculiar
name

name of the radical principle, added to that of the genus, may serve to distinguish each acid in particular. Thus, sulphur is the *radical* of the *sulphuric acid*; phosphorus, of the *phosphoric acid*; carbone of the *carbonic acid*, &c.

IX. Although this nomenclature possesses the advantage of expressing, with precision, the nature of every different acid, yet, it has not, hitherto, been applied to all the acids; because the radicals of some of them, are still unknown; and of others, the radicals are themselves so compound, that their names could not be introduced into those of the acids to which they respectively belong, without producing too great a multiplicity of words.

X. The acidifiable radicals may be combined with more or less oxigene; and in this view, are susceptible of two different states of acidification. In the *one*, they are combined with the smallest portion of oxigene that is not insufficient to render them acid; and in this case, their acidity is very weak, and they act with but little energy on those bases which form with them, neutral salts: In the modern systematic chemical nomenclature, this state of combination and acidity, is denoted by terminating the name of the weak acid in the syllable *ous*: Thus, we say the sulphureous, the nitrous, the phosphorus, the acetous acid, &c. The *second* state of acids, is that in which they contain a larger proportion of oxigene, and are for the most part completely saturated with it: They then possess all the attractive energy of which their acid nature is capable; and this state is expressed in the new nomenclature, by the final syllable *ic*, in contradistinction from *ous*: Thus we say the sulphuric, the nitric, the phosphoric, the acetic acids.

XI. In regard to the proportion of oxigene combined with the acidifiable radicals, what is said in the last section, may even be greatly extended in its signification. Every radical may be considered as capable of existing in four different states: 1. As containing very little oxigene, not even enough

to give it any thing of an acid nature ; and in this state, it is but an oxide ; such as sulphur coloured red or brown by exposure to the air ; which is but an oxide of sulphur : 2. As containing more acid, than in the former case, so much as is sufficient to render the compound a weak acid ; and such is the sulphureous acid, &c.: 3. As containing still more oxigene than in the second case, and being now so saturated, as to constitute a powerful acid ; such is the sulphuric acid : 4. Lastly, As containing a portion of superfluous oxigene, above what is requisite to render it a strong acid ; it is now called an *oxygenated*, or even a *super-oxygenated acid*.

XII. From these foregoing facts, it appears, that there are two ways of forming acids at pleasure, with these several proportions of oxigene. In *one*, we combine the radicals with the quantities of oxigene which are precisely necessary to bring them into the new state that we desire to produce ; as is done with sulphur, phosphorus, and arsenic. In the *other*, we detach from those acids which contain the greatest possible quantity of oxigene, certain proportions of the acidifying principle, by means of those combustible bodies with which it most eagerly combines.

XIII. This last method depends on the attractions of oxigene for the different combustible bodies, and is often successfully employed, to effect the entire decomposition of acids, by abstracting all the oxigene contained in them. Acids, by this means, inflame combustible substances. In order to this, it is only necessary, that the acids employed, contain no solid oxigene ; and that the inflammable matters brought into contact with them, be able to absorb the oxigene which those acids contain, into a state more solid than that in which it exists in the acids. It is not, however, every one of those acids which are decomposable by combustible bodies, that can heat the combustible matter to inflammation.

XIV. Heated charcoal is employed with sufficient success, to decompose all the acids susceptible of this decomposition.

But there are other combustible bodies which serve the same purpose. Such are most of the metals, phosphorus, sulphur, hydrogen in that dry and solid state in which it exists in its vegetable compounds.

XV. All the acids owing, as has been explained, their specific differences to their respective radical principles; they may be distributed into four classes, the distinctions of which shall be founded upon the *nature* of the radicals, as it is *known* or *unknown*, *simple* or *compound*.

A. The *first* of these classes, contains those acids of which the radicals are known and simple; that is, which are formed of undecomposed combustible substances, united with oxygen. It comprehends the following species; the sulphuric acid, the nitric acid, the carbonic acid, the phosphoric acid, the arsenic acid, the tungstic acid, and the molybdic acid.

B. The *second* class include acids having unknown radicals, but such as are strongly suspected to be simple. The muriatic acid, the fluoric acid, and the boracic acid, are of this character.

C. I rank in the *third* class, acids of which the radicals are known to be of a binary composition. Such are the vegetable acids, whose common radical is composed of hydrogen and carbon. The succinic acid belongs likewise to this class.

D. The *last* class consists of acids, the radicals of which, are composed, each at least of three different substances. Such are the animal acids, which have for their radicals, combinations of carbon, hydrogen, and azote.

XVI. Not only are these several classes of acids, distinguished by general characteristics, marking each class: But even each particular acid has its peculiar properties, by which its character is discriminated from the characters of all other acids. These properties may even be expressed by words and phrases, not less simple and easy than those which Linnæus taught

taught naturalists to employ. A sketch of this mode of expressing these properties, follows below.

XVII. The acids with simple and known radicals, are all decomposable by combustible bodies, which they burn with more or less activity ; and are thus reduced to their radicals. By this decomposition was the nature of the radicals first discovered. These acids may be also composed anew, by uniting **oxigene** with their radicals.

The acids, whose radicals are unknown, but from strong analogies, suspected to be simple ; have no other classific character, but that of being indecomposable by combustible bodies, and not to be formed by art.

The vegetable acids, with binary radicals, are characteristically distinguished ; 1. By being all decomposable by a strong heat, and by the addition of a due quantity of **oxigene**. 2. By affording, when they are thus decomposed, water and carbonic acid ; which are formed by the preparation of their hydrogen and carbone, and by the union of each of these bodies, separately, with **oxigene** : 3. By their slow, spontaneous decomposition, when they are dissolved in water, and exposed to a temperature above $54\frac{1}{2}^{\circ}$ F. : 4. Because they cannot be decomposed by any known combustible body ; since their radical is compounded of two substances, which are remarkable, as having the strongest possible attraction for **oxigene** : 5. Because they are mutually convertible in consequence of differing from one another, at the first, in nothing else but the proportion of their principles.

The more compound acids with three or more radicals, which derive their origin from animal matters ; although the least known of all the acids ; have also some properties which may be regarded as their classific characters. Such are, the property of yielding ammoniac, when they are decomposed by fire, and of affording Prussic acid by a change in the proportion of their principles.

XVIII.

XVIII. To these classific characters, we shall next add the specific characters ; and shall here endeavour to employ a systematic, technical language, similar to that of the botanist, and the zoologist.

Acids of the first class, having radicals which are simple and known.

A. Sulphuric acid ; formed from sulphur and oxigene, by the combustion of the sulphur ; inodorate, twice as heavy as water, very caustic, less volatile than water ; affording sulphureous acid gas and sulphur, by its decomposition with *red-hot coal*, metals, &c. ; forming sulphates with the earths, alkalis, and metallic oxides.

B. Sulphureous acid, highly odorate, very volatile, gaseous ; destructive to blue vegetable colours, and fit to cleanse away spots made with these colours on a white ground ; absorbing, by low degrees, the oxigene from the air, and from various acids or oxides ; forming sulphites with the earthy and alkaline bases.

C. Nitric acid, liquid, white, caustic, of a strong nauseous smell ; formed of azote and oxigene ; capable of inflaming sulphur, charcoal, zinc, tin, and oils ; liable to lose, by the action of combustible bodies upon it, various proportions of its oxigene, and thus producing nitrous acid, nitrous gas, and nitrous oxide ; destructive to colours ; possessing the power of burning vegetable and animal substances, making them yellow, and converting them into acids ; decomposing that ammoniac which is produced by the putrefaction of animal matters ; forming nitrates with the earths and alkalis ; remaining in an imperfect union with metallic oxides, and having a tendency to acidify them.

D. Nitrous acid, or nitric acid with an inferior proportion of oxigene ; in the form of a gas, red or orange coloured ; extremely volatile, discolouring vegetables, becoming blue and green with water ; communicating a yellow colour to nitric acid, when united with it in various proportions ;

D

yielding

yielding nitrous gas, under the contact of combustible bodies; and forming nitrites with the earths and alkalis.

E. Carbonic acid is formed of carbone in the proportion of 0,28 parts, united with 0,72 of oxigene; is a gas heavier than common air, which it displaces; fills subterraneous cavities; is evolved from liquors in vinous fermentation; extinguishes lamps, kills animals, reddens only light blue vegetable colours; produces a precipitate of chalk in lime-water, but again dissolves the chalk in the water; mineralizes acidulous waters, and enters into combination with barytes, lime, copper, iron, and lead in mines and quarries; forms carbonates with the earths, alkalis, and metallic oxides; is decomposable only by phosphorus, and when it is in union with alkaline bases, particularly with soda, in the state of a carbonate.

F. The phosphoric acid is composed of phosphorus and oxigene, combined by a rapid and entire combustion; is liquid, thick, or solid, vitrifiable by fire; dissolves silices, whilst in the act of vitrification; is decomposable by carbone, by which it is reduced to simple phosphorus; and forms phosphates with the earths, alkalis, and metallic oxides.

G. Phosphorous acid differs from the phosphoric, only in containing less oxigene; is volatile, and odorate; detaches oxigene from many other bodies; and forms phosphites with terrene, alkaline, and metallic bases.

H. The arsenic acid is formed of the metal called *arsenic*, in union with oxigene. Combustion reduces arsenic only to an oxide; and the nitric, or the oxigenated muriatic acid, is then necessary to afford the additional quantity of oxigene requisite to convert the oxide into acid. The acid thus obtained is fixed, fusible into a glass, decomposable by the action of a large quantity of light and caloric, and by many combustible bodies; forms arseniates with earth, alkalis, and metallic oxides. The oxide of arsenic which combines also with the

the same bases, may be regarded as a sort of *arsenious acid*.

I. Tungstic acid is a compound of the metal of tungsten, with oxigene; exists in the form of a white or yellowish powder, fixed, infusible, scarcely soluble, reducible into tungsten by hydrogen, carbone, &c.; forms the native tungstate of lime, which is called *Lapis ponderosus*, and the native tungstate of iron, or *wolfram* of mineralogists.

K. Molybdic acid is a compound of the metal named *molybdena*, with oxigene; is of a harsh taste; is like the two acids last preceding, metallic; exists in the form of a white powder; becomes blue by the contact of those bodies which reduce it; and then by the loss of its oxigene, passes back into the state of molybdena.

Acids of the second class, of unknown radicals.

XIX. The acids of which the radicals are unknown, but suspected to be simple, are three in number; the muriatic acid, the fluoric acid, and the boracic acid.

A. The muriatic acid is a gaseous or fluid substance, of a pungent smell, unalterable by any known combustible body; deprives all combustible bodies, particularly metallic oxides, of their oxigene, and is thus changed into *oxigenated muriatic acid*. Oxigenated muriatic acid is remarkable for its greenish yellow colour; its power of thickening and constricting the organs of animal bodies; its property of destroying the colours of vegetable substances, and of inflaming the most part of combustible bodies; its capacity to form with potash, a salt which rapidly kindles hot inflammable matters, and produces the purest vital air that is known.

B. The fluoric acid is a gaseous substance; forms in the air, a very thick white vapour; corrodes glass; dissolves silicious earth; and with this earth forms a permanent gas, from which water separates a part of the silica.

C. The boracic acid is dry, crystallized in hexahædral plates, fusible into a glass, almost insipid, scarcely soluble, fusible with silices, very feeble in its affinities, and liable to yield up the terrene and alkaline bases to almost any other acid.

Acids of the third class, having binary radicals.

XX. The acids with binary radicals, mixed or compound, belong almost exclusively to the vegetable kingdom, and are formed by the union of carbonated hydrogen, or hydrogenated carbone, with oxygen in various proportions; which, as was before observed, accounts for their reciprocal conversion into one another. These acids are considerably numerous; and their number may probably be augmented by progressive discoveries. I have therefore divided them into five genera, distinguished from one another, by generic differences in their formation. The *first* of these genera includes those pure acids which are formed in vegetables; comprehending the succinic acid, which is evidently of vegetable origin: In this genus, are five species; the succinic acid, the citric acid, the gallic acid, the malic acid, the benzoic acid. The *second* genus contains those vegetable acids, which are fully formed in vegetables, but are at the same time partly saturated with potash; they are called acidula; they are two species; the tartareous acidulum, and the oxalic acidulum. In the *third* genus, I rank all acids which are formed by the action of the nitric acid, and the precipitation of its oxygen, upon vegetable substances: Of this genus, we know as yet only the distinct species of the camphoric acid: The oxalic and malic acids indeed, are not unfrequently formed from vegetable matters, treated with nitric acid. In the *fourth* genus, I place those acids which are formed in vegetables by treatment with fire; such as the pyromucous, the pyro-ligneous, and the pyro-tartareous acids. The *fifth* genus consists of vegetable acids produced by fermentation; of this

this genus we know none but the acetous species. The following are the specific characters of these twelve acids.

A. The succinic acid is disengaged and sublimated from heated amber; is of a strong bituminous smell, oleaginous and inflammable, volatile, crystallizable into needles; forms permanent crystallizable salts, particularly with metallic oxides; and adheres more tenaciously to the three earths, than to the alkalis.

B. The citric acid is crystallizable into rhomboidal plates; is not convertible into oxalic acid by the nitric acid; has a more powerful affinity with the earths, than with the alkalis; is readily decomposed in water, or by fire.

C. The gallic acid exists in abundance in nut-galls; is crystallized into small grey or yellowish needles; is styptic; produces a black precipitate from solutions of iron; reduces metallic oxides which it finds in union with other acids; is convertible into oxalic acid by the nitric acid.

D. The malic acid abounds in apples; is not crystallizable; is convertible into oxalic acid by the nitric acid; is formed, at the same time as the oxalic acid, or even more quickly, in vegetables treated with nitric acid.

E. The benzoic acid is obtained from benzoin, storax, balsam of Peru, vanilla, and cinnamon, by means of heat; is crystallizable into flattened prisms; has an aromatic smell when heated; is fusible by a gentle heat; is volatile, inflammable, scarcely soluble in water; is soluble, but not decomposable by the nitric acid.

F. The tartareous acidulum, is formed of tartareous acid, imperfectly saturated with potash; exists in wines; is crystallizable, and decomposable by fire; affords a large proportion of carbonic acid and oil, with a plentiful residue of carbonate of potash; by distillation, yields pyro-tartareous acid; is scarcely soluble; is decomposable in water; forms triple salts with the alkalis and metallic oxides; becomes highly soluble upon the addition of borax or boracic acid to it. The

tartareous acid obtained from this acidulum, is crystallizable into needles interwoven together; is unalterable in the air, is highly soluble, affords acidulum, upon receiving the addition of a small portion of potash; decomposes so much of sulphate, nitrate, or muriate of potash, or soda, as may afford potash sufficient to reduce the acid to acidulum; is convertible into oxalic acid by the action of the nitric acid.

G. The oxalic acidulum is formed of oxalic acid partially saturated with potash; is obtained as an extract from salt of forrel; is crystallized in parallelipeds; is hardly decomposable by fire; detaches lime from any other acid; is precisely similar to the acidulum formed by the nitric acid, when it is brought into contact with any vegetable matter whatsoever; is unalterable by the nitric acid; is the least decomposable, and the most oxygenated of all vegetable acids.

H. The camphoric acid is formed by the action of the nitric acid distilled upon camphor; is crystallizable in parallelipeds; forms with earths and alkalis, neutral salts that are highly crystallizable; does not, like oxalic acid, abstract lime from all the other acids; is very little known.

I. The pyro-tartareous acid is a modification of the tartareous acid, produced by fire; has the smell and colour of a burnt body; is very easily rarefied; and bubbles up very much, under the action of heat; is not crystallizable; forms with earthy and alkaline bases, salts different from those which the tartareous acid yields with the same bases; is but little known.

K. The pyro-mucous acid is formed by the distillation of gums, sugar, and fecula; has a lively agreeable odour of caramels; is volatile; colours vegetable and animal matters with a red hue; is decomposable by intense heat; is but little known.

L. The pyro-ligneous acid is obtained from wood by distillation; has a pungent, foetid smell; is not crystallizable; is decomposable by a strong heat; is volatile; forms peculiar

salts with earths, alkalis, and metallic oxides; has peculiar attractions for these bases; and as to its other qualities and relations, is not better known than the two species last preceding.

M. The acetic acid is formed by the fermentation of wine, and is on this account named *Vinegar*; has an agreeable taste and smell; is liquid, volatile, and decomposable by ardent heat; is liable to be supersaturated with oxygen, when it is distilled with metallic oxides; and becomes in consequence of this change acetic acid or *radical vinegar*; which is much more acid and more odorous than the acetic acid; and is also inflammable, and mixed with alcohol.

Acids of the fourth class, with ternary radicals,

XXI. The acids whose radicals are ternary compounds; and which have been in general described as consisting of carbone, hydrogen, and azote in union with oxygen, belong chiefly to the animal kingdom. They are still less known than those of the third class. But, seeing that they all furnish ammonia by decomposition with fire, and Prussic acid by a change in the proportion of their principles; I am led to observe, that the Prussic acid seems to stand in the same relation to this genus of acids, as that of the oxalic acid to the vegetable acids in general. When animal substances are by treatment with nitric acid, converted into oxalic acid, there is constantly formed at the same time, a portion of Prussic acid, which is discharged in vapours.

There are seven known animal acids, which appear to belong all to this genus of compounds; namely, the lactic acid, the saccho-lactic acid, the sebatic acid, the lithic acid, the formic acid, the bombic acid, and the Prussic acid. Each has its characteristic properties.

A. The lactic acid is formed by the addition of a small portion of acetic acid to milk spontaneously soured; is not crystallizable; is soluble in alcohol; yields by distillation,

an acid analogous to the pyro-tartarous acid; forms deliquescent salts with the terrene and alkaline bases; decomposes alkaline acetates.

B. The saccho-lactic acid is precipitated in a white powder from the oxalic acid formed by sugar of milk and nitric acid; is almost insipid, and almost insoluble; is decomposable by fire, and yields by this decomposition, a sublimated salt, having the odour of benzoin, and which forms crystallizable salts with the alkalis; is very little known.

C. The sebacio acid is obtained from grease by the action of fire, and is separated likewise from grease by the alkalis and lime, with the help of a strong heat; is liquid, white, fuming, very acrid in odour and taste; forms crystallizable and fixed salts with earth and alkalis; decomposes muriate of mercury; is decomposable by a strong heat.

D. The lithic acid exists in human urine; forms the stone in the bladder; is dry, crystallized in flat needles almost insipid and insoluble, in part volatile, decomposable by a strong heat; yields ammoniacal carbonate and Prussic acid when heated with fire; forms with nitric acid, a solution of a beautiful red colour; is soluble in caustic alkali; is precipitated from the urine of persons under fever, with a reddish or greyish colour.

E. Formic acid is extracted from ants or *formicae*, by distillation, or squeezing with water; reddens blue flowers of vegetables, even in the living insect; is evolved in a strongly odorous vapour; its smell resembles musk; kills animals in this gaseous form; is fit for the same domestic uses as vinegar; is decomposable by a strong heat; attracts oxygen from oxygenated muriatic acid; is often stronger than the sulphuric acid; forms with alkalis and earths crystallizable and non-deliquescent salts.

F. The bombyc acid is preserved in a reservoir, situate near the anus of the chrysalis of the silk-worm; is extracted from this reservoir by compression, or by means of alcohol; is mingled,

mingled, in the steam with a brown oil and a gum; is liquid, of an amber yellow colour, spontaneously decomposable; yields Prussic acid by distillation, and with the nitric acid; is not known in its combinations.

Gas Prussic acid, which saturates iron, and gives it the colour of Prussian blue, is at present obtained by the distillation of blood, by the action of the nitric acid upon the albumen, the gluten, or the fibres, &c. of animals; is evolved, while a formation of oxalic acid takes place; is remarkable for a fetid, acrid smell, resembling that of bitter almonds; is easily decomposable by a great heat, and on decomposition, yields ammonia; is capable of assuming the form of gas; attracts metallic oxides from many of the other acids; may be formed by the union of hydrogen, carbon, azote, and oxygen; is slightly acid in its taste; and contains, as it should seem, but little oxygen.

XXII. From what is here laid down, it follows, that the acids which have been divided into two classes, as being simple or compound in their radicals; differ yet more essentially in this; that the acids of the former class, are not mutually convertible into one another; because there is a wide difference between the properties of one simple radical, such as sulphur, and those of another, as for instance phosphorus.

To effect the mutual conversion of any two acids with simple bases, it would be necessary to begin with converting their radicals into one another; a change which is far from knowing how to accomplish. The second class of acids, on the contrary, being in general formed of a base compounded of hydrogen, carbon, and azote, and combined with oxygen, appear to differ from one another, only in possessing different proportions of the two or three principles in the composition of their radical; and in the proportion of the oxygen by which the radical is acidified. They have a tendency to experience continual variations in the proportions of their composition; especially

cially under the influence of change of temperature, moisture, &c.; and they thus pass spontaneously into different states. Thus, for instance, by the efforts of vegetation merely, plants come to contain different acids at different periods in their growth. Thus, solutions of vegetable acids in water, are altered, suffer a change of nature, and at last yield all, more or less of carbonic acid and water, when they reach the ultimate period of their decomposition.

~~XXIII.~~ These truths being clearly comprehended, we cannot fail to perceive, that there remains yet to be discovered, not only the nature of several acids, the composition of which is unknown; but even the existence of perhaps a considerable number of new acids in plants and animals. For among the products of those organized beings, of which we have begun to investigate the principles, we are as yet far from having exhausted all the possible combinations of carbone, hydrogene, azote, and oxigene; as a very slight calculation will readily shew. To this order of researches and discoveries, is to be referred, the examination of those acids which are said to exist in cork, in grey pease, and in various vegetable matters, as also in the clot of the blood—*cruoric acid*, and in the gastric juice, &c. It will also be perceived, upon inspecting the particulars of the chapter immediately subsequent, that most metals, when burnt, appear to assume an acid character, and to act the part of acids in many combinations. Acid substances, therefore, seem to be the most numerous of all bodies, and to act the most important part in all those chemical alterations which bodies, simple and compound, incessantly undergo.

Application of the above propositions.

The artificial formation of sulphuric acid by the combustion of sulphur in the great way.

The extraction of colour from white linens and stuffs by sulphureous acid.

The

The new arts of bleaching, by the oxygenated muriatic acid.

Theory of the *Aqua Regia* of ancient chemists.

The art of engraving on glass with the fluoric acid.

Part of the theory of the formation of artificial nitre-works.

The existence and formation of the known native acids.

The influence of the acids in mineralization.

The extraction and purification of vegetable acids and acidula.

The spontaneous formation and destruction of vegetable acids.

The mutual conversions of those acids and acidula into one another by vegetation, fermentation, &c.

C H A P.

CHAP. VIII.

Of the Union of the ACIDS with the EARTHS and ALKALIS.

I. ALL the acids combine without decomposition, with the alkaline earths, and the alkalis. These combinations have been termed *neutral salts*, *middle salts*, *compound salts*, *secondary salts*. The two former of these names, are not correctly applicable to them, except when they are neither acid nor alkaline; the two latter are more accurate, and more useful. All these salts are easily formed by art. Nature exhibits a great number, especially of those which are formed by acids of simple radicals. Mineralogy is daily obtaining the knowledge of new salts of this character, by the analysis of minerals, which can alone explain their intimate nature.

II. All these compound salts require to be distinguished by two names; one expressing the acid; the other, the terrene or alkaline base. The first of these names may have two variations of termination, corresponding to two different states of the acid in the compound salt. The termination *ate* may be employed, when the acid is one of those which are completely saturated with oxygen, and whose names end in *ic*; thus the salts compounded with the *nitric acid*, may be called *nitrates*. Words terminating in *ite*, will serve to distinguish the

the presence of those weak acids which are not fully saturated with oxigene; and which when alone have names ending in *oxy*: thus *nitrites* are salts compounded with the *nitrous acid*.

III. As there are thirty-four species of known acids, and seven bases, terrene and alkaline, susceptible of such combination as forms compound salts, the number of these compound salts might be stated at 238. But this enumeration would be far from accurate: 1. For there are but a few acids susceptible of combination with silices: 2. Because there are other acids, which, on account of their weakness, cannot, without undergoing decomposition, enter into union with terrene bases, or with ammoniac: 3. Because there are various acids capable of combining with the same bases in three different ways,—or of three different states of saturation with those bases; namely, with excess of acid, in the exact neutral state, and with excess of base. Neither can we exactly determine the number of the terrene and alkaline compound salts; for we are as yet far from having examined those combinations so fully as to know them well, and to be certain whether they may not be susceptible of various saturations, &c.

IV. As the acids have all different elective attractions or affinities for every different terrene or alkaline base; it would be necessary for us to know all these different affinities, in order that we might have a complete history of the compound salts. But only a small number of these affinities have hitherto been exactly determined: We are too far from possessing all the assemblage of facts, necessary to throw due light upon these bodies: We have not as yet thoroughly examined a tenth part of them.

V. To enter regularly upon the history of compound salts, we must divide them into genera and species, and ascertain their genera and specific characters. Of this part of the history of these salts, only a slight sketch can be here given; because chemists have hitherto paid small attention to it, although it being of the utmost importance, to apply the methods of

botany to the enunciation of the chemical properties of these and other bodies.

There are two modes which may be employed for the systematic arrangement of the compound salts. Of these, one is founded upon the consideration of the nature of the acids; the other refers to the nature of the bases. We cannot as yet form genera which shall comprehend all these salts, otherwise than upon the nature of the acids; for the acids alone can furnish us with generic characters; the influence of the bases upon the properties of these compounds, is not yet so adequately known, as that we can employ these alkaline and terrene substances, as the heads of generic divisions.

VI. We may reckon five and thirty genera of compound salts, corresponding to the number of the acids. The generic names are taken from the acids respectively. The following are the denominations of the thirty-five genera.

- I. Genus, SULPHATES.
- II. Genus, SULPHITES.
- III. Genus, NITRATES.
- IV. Genus, NITRITES.
- V. Genus, CARBONATES.
- VI. Genus, PHOSPHATES.
- VII. Genus, PHOSPHITES.
- VIII. Genus, ARSENIATES.
- IX. Genus, ARSENITES.
- X. Genus, TUNGSTATES.
- XI. Genus, MOLYBDATES.
- XII. Genus, MURIATES.
- XIII. Genus, OXIGENATED MURIATES.
- XIV. Genus, FLUATES.
- XV. Genus, BORATES.
- XVI. Genus, SUCCINATES.
- XVII. Genus, CITRATES.
- XVIII. Genus, GALLATES.
- XIX.

- XIX. Genus, MALATES.
- XX. Genus, BENZOATES.
- XXI. Genus, TARTRITES.
- XXII. Genus, OXALITES.
- XXIII. Genus, CAMPHORATES.
- XXIV. Genus, PYROMUCITES.
- XXV. Genus, PYROLIGNITES.
- XXVI. Genus, PYRO-TARTARITES.
- XXVII. Genus, ACETATES.
- XXVIII. Genus, ACETITES.
- XXIX. Genus, LACTATES.
- XXX. Genus, SACCHO-LACTATES.
- XXXI. Genus, SEBATES.
- XXXII. Genus, LITHIATES.
- XXXIII. Genus, FORMIATES.
- XXXIV. Genus, BOMBIATES.
- XXXV. Genus, PRUSSIATES.

VII. Every one of these five and thirty genera of compound salts which are here enumerated, is to be considered, with regard to its distinctive characters, or to those properties which serve to distinguish it from every other genus, and to afford clear notions of those differences by which all the genera are mutually discriminated. We must, for this end, chuse out one single property if possible, or at the utmost, two or three properties, strikingly different from one another, in every genus; and thus find the peculiar characters of all the genera. The following is an attempt at this.

I. Genus, SULPHATES; decomposable by charcoal, &c. into sulphures.

II. Genus, SULPHITES; yield, by the contact of almost any acid, the smell of burning sulphur with effervescence.

III. Genus, NITRATES; kindle combustible bodies, at almost any temperature; and are almost all reduced to their base by the action of fire.

IV. Genus, NITRITES ; decomposable by weak acids which separate from them a red nitrous vapour.

V. Genus, CARBONATES ; in which the characters of the bases still remain more or less eminent ; and which, with all the acids, exhibit a brisk and discernible effervescence, that proceeds till the carbonic acid be wholly disengaged.

VI. Genus, PHOSPHATES ; decomposable. mediately or immediately, by charcoal, which separates the phosphorus.

VII. Genus, PHOSPHITES ; all immediately decomposable by charcoal, which separates the phosphorus ; and affording vapours by the contact of the sulphuric acid, &c.

VIII. Genus, ARSENIATES ; yield by the contact of burning coals, the odour and the white vapour of arsenic ; are not decomposable by acids alone, or without a double affinity.

IX. Genus, ARSENITES ; the arsenious acid is separated and precipitated from their solutions, by the contact of any other acid,—even by that of the arsenic acid.

X. Genus, TUNSTATES ; become yellow at the contact of the nitric or the muriatic acid.

XI. Genus, MOLYBDATES ; these are to be known, as yet, only by their affording molybdic acid, when treated with other acids ; and by the peculiar properties of the molybdic acid.

XII. Genus, MURIATES ; yield muriatic acid, at the contact of the concentrated sulphuric acid ; and oxygenated muriatic acid, by the contact of nitric acid.

XIII. Genus, OXIGENATED MURIATES ; kindle all combustible bodies, at a lower temperature, than do nitrates, with a brisk flame ; and after this combustion, remain in the state of simple muriates.

XIV. Genus, FLUATES ; emit, at the contact of concentrated sulphuric acid, a vapour that corrodes glass.

XV. Genus, BORATES ; fusible, with or without the separation of their bases ; yield by solution, in union with another acid,—boracic acid in foliated crystals.

XVI. Genus, SUCCINATES ; we cannot distinguish and characterise, without first decomposing them, and observing their acid ; they for the most part retain a smell of burnt amber.

XVII. Genus, CITRATES ; are not sufficiently known to be discriminated by generic characters ; in order to distinguish them, we must separate the citric acid by the use of the strongest mineral acids.

XVIII. Genus, GALLATES ; these are all very clearly characterised by the property which they possess, of producing a black precipitate from solutions of iron ; and of effecting a partial reduction of the oxides of silver, gold, and mercury, — at the same time, when they separate them from their solutions.

XIX. Genus, MALATES ; are almost all deliquescent ; are to be distinguished only by a partial extraction of their acid, by means of mineral acids.

XX. Genus, BENZOATES ; their genus may be determined by the smell which they emit of the benzoic acid ; and by their affording this acid, when exposed to the action of other more powerful acids.

XXI. Genus, TARTRITES ; we find characters sufficiently striking, to distinguish these salts, in their tendency to form triple salts, and acidula less soluble than the pure acid and the neutral salts which that acid forms with the same bases.

XXII. Genus, OXALATES ; their tendency to form acidula scarcely soluble ; and the property which they possess of decomposing all calcareous salts ; are sufficient to distinguish them.

XXIII. Genus, CAMPHORATES ; are too little known, for us to be able to assign them, generic characters ; they are to be distinguished by the presence and the properties of the camphoric acid, partially obtained from them.

XXIV. Genus, PYROMPCITES; in the same case as the camphorates.

XXV. Genus, PYROLIGNITES; equally unknown.

XXVI. Genus, PYRO-TARTARITES; cannot be characterised.

XXVII. Genus, ACETATES; still but indistinctly discriminated from acetites; yield, when decomposed by mineral acids, a very strong, and a very pungent white vapour;

XXVIII. Genus, ACETITES; all to be distinguished by their acid, separated from the base by other more powerful acids.

XXIX. Genus, LACTATES; are very little known; distinguishable only in their acid, separated by other acids.

XXX. Genus, SACCHOLACTES; like the lactates, unknown.

XXXI. Genus, SEBATES; affording the white vapour, and the acrid odour of the sebatic acid, at the contact of the more powerful mineral acids.

XXXII. Genus, LITHIATES; in their attractions, the feeblest of all acids; decomposable even by carbonic acid.

XXXIII. Genus, FORMIATES; very little known, and only distinguishable by their acid.

XXXIV. Genus, BOMBIATES; not better known than the formiates.

XXXV. Genus, PRUSSIATES; clearly characterised by their power of forming Prussian blue, with solutions of iron.

VIII. To determine the specific characters of nearly 245 species which these thirty-five genera contain; they must be studied with deep and assiduous care. In this department, the science of chemistry, is not yet far advanced. Wanting such knowledge, let us at least endeavour to distinguish the path we must follow in order to complete the history of these compounds, and to fix a proper method of studying their properties.

Every

Every compound salt, terrene or alkaline, exhibits to the observer, the following particulars.

1. Form, and the varieties of form. These are to be geometrically described. The inclination and the degrees of the angles ; the primitive formation of the crystals ; their interior form ; their dissection ; and the laws of diminution which determine their varieties ; ought to be all remarked and expressed.

2. Its existence in nature or art ; the comparison of the native with the artificial salt.

3. Its taste.

4. The action of fire upon it ; which may be either nothing at all, or fusing, vitrifying, sublimating, decomposing, &c.

5. The action of light.

6. The influence of air, which may be either negative, or such as to furnish or abstract water of crystallization.

7. Its union with water ; the quantity necessary to its solution, at different temperatures ; the caloric then absorbed or disengaged ; the crystallization effected by cooling or evaporation.

8. The attraction of earths, modifying, decomposing, not affecting, or entering into a triple compound with—the salt.

9. The effect of the alkalis upon it, which may be negative, decomposing, or sometimes forming a triple compound.

10. The comparative action of the acids different from that existing in the compound salt ; and this is either such as to decompose, and destroy the peculiar nature of the salt, or such as to produce no effect upon it.

11. The influence of the neutral salts upon it ; which is either negative, or tending to form a triple salt by entire combination ; or effecting a double decomposition by which the bases and acids are reciprocally changed ; or producing a precipitation in consequence of the attraction of some of the substances for water.

12. The solubility or insolubility of the salt in alcohol.

13. Its alteration or inalterability by charcoal, decomposition of its acid, or leaving it unaffected.

14. The influence of vegetation and fermentation upon the salt.

15. Its action on the animal œconomy.

IX. If in the present state of chemistry, all these inquiries could be satisfactorily answered; the history of the compound salts, terrene and alkaline, would then, not only be complete, but would throw great light on many of the phenomena of nature and art, which are, as yet, but little understood.

X. We are already acquainted with some saline combinations of an acid with two bases;—and these bases are more especially magnesia and ammoniac. Such compounds are denominated triple *salts*. But, there are probably many more of them than we yet suspect; and these demand all the attention of chemists. The earth exposes both at its surface, & in its cavities near the surface, various saline compounds differing from those which art produces,—in that the former alone exhibit the simultaneous existence of two bases even of two acids. Borate of lime, and borate of magnesia have been already found crystallized together in *quartz*; sulphate of lime and fluoate of lime, in earth of maroch, and stone of Estremadura, &c.

Application of the foregoing propositions.

The knowledge of native salts.

The crystallization and purification of useful salts.

The phenomena of solutions.

The precipitation and preparation of alumina, magnesia, &c.

The attraction of lime, potash, soda, and ammoniac for acids.

The formation of neutral salts in nature.

All the particular facts relative to the manufacture of salts.

The preparation of the nitric, muriatic, boracic, &c. acids.



CHAPTER IX.

OXIDATION and SOLUTION of METALS.

I. IN the sixth chapter preceding, we have considered metals as combustible bodies undecomposed or simple, and characterised by their more remarkable properties. But those general facts are not sufficient. The part which metals act among the phenomena of nature, and in the processes of art, requires us to examine them particularly, and in such detail, that we may rightly estimate the full extent of their varied influence.

II. Although metals be capable of mutual combination in their metallic state, as well as of union with sulphur, phosphorus, carbone, and with all combustible matters in general; yet they are more commonly combined with oxygen, before entering into combination with any other substances: Or, in other words, in order to enter into most of the compounds in which they are known to exist; they must first be combined with oxygen, or reduced to the state of burnt bodies. All the singular phenomena which the metals exhibit in their combinations; all the changes of form which they undergo; are owing to their attraction for oxygen, and to the varying proportions in which they possess this principle.

III.

III. Although there be many cases in which the metals are susceptible of combination with oxigene; yet these may all be reduced to three general heads. The first is *the contact of air*, assisted by the action of caloric; the second is owing to the *decomposition of water*; the third, to the *decomposition of acids*. In this threefold point of view, we shall here consider the oxidation and solution of metals.

IV. All metals heated in the air, and raised to a certain temperature, higher or lower, before or after their fusion, are liable to burn with a brisk flame, an ardent heat, and a real deflagration. They then absorb oxigene in a more or less solid state. Such as are oxidated slowly, and without any sensible inflammation; nevertheless disengage light and caloric from vital air; but in quantities so small, that the light and caloric do not, during their disengagement, become perceptible to our organs.

V. Rise of temperature favours the absorption of oxigene from the atmosphere, by metals; and renders the combination of this principle with these combustible bodies, more solid than it would otherwise be.

VI. While some metals burn in the air, only at a very high temperature,—such as gold, silver, and platina; there are others that burn at any temperature, even at the lowest and with the utmost readiness; such as manganese which is oxidated, and crumbles down into a powder, in the space of a few hours, by the contact of air merely, and this even several degrees under zero. Some metals, such as iron, copper, lead, &c. burn slowly, and in the course of a few months in the air, even cold.

VII. All metals increase in weight during this process, which never takes place without the access of air; and absorb a new principle of oxigene from the atmosphere, without losing any thing of their former substance. The name of *calcination* formerly given to this phenomenon, cannot now be retained, any more than the term *metallic calces*. The words *combustion*,

combustion, and *oxidation*, are now employed to express this process; as is the phrase *metallic oxide*, to distinguish metals which are burnt in it.

VIII. The colours which metals exhibit, as they burn, or with which their flame is tinged, appear to owe their origin to the solution of metallic particles in the light that is disengaged: thus copper affords a green flame; &c.

IX. Not only do all metals, compared with one another, in their combustion by the contact of air, absorb different quantities of oxygen, in order to their saturation; but likewise each metal considered by itself, absorbs various proportions, and stops at different points of oxidation, according as the degrees of its temperature vary. Thus tin, lead, copper, iron, change their colour, and are studded with the tints of the rainbow, at the lowest degrees of heat to which they are exposed in contact with air: lead first becomes a grey oxide, then a yellow, and at last a red oxide; mercury passes from black to white, from white to yellow, from yellow to red; iron at first a black oxide, becomes next a green, then a brown, and at last a white oxide; copper is first a brown oxide, then a blue, and in its last degree of oxidation, takes a green colour.

X. The metals differ all from one another, in their attractions for oxygen. There are some, which light, almost alone, and with very little caloric, is able to deprive of their oxygen, such as gold, silver, &c. Others require in order to separate the oxygen, a great degree of heat, and much light; such as mercury. Lastly, most metallic oxides do not yield their oxygen to caloric and light alone, and unassisted by other matters. To decompose these last oxides, they are heated with charcoal which deprives them of their oxygen.

XI. In consequence likewise of this diversity in the attractions of the metals for oxygen, some metals will abstract the oxygen from the oxides of other metals; almost any other metal detaches oxygen from gold or silver; copper detaches

is from mercury, iron from copper, &c. These attractions are not, as yet, all well known. What we do know of them, indicates the following to be the order of the attractions of these several metals for oxigene; beginning with that which is the strongest; manganese, zinc, iron, tin, copper, mercury, silver, gold.

XII. Several metals decompose water; and accomplish this in much the more sensibly or rapidly in proportion as their temperature is higher; because then the great quantity of the caloric employed, more powerfully attracts and dissolves the hydrogen. Thus fire decomposes water with great energy, at a white-red heat; but cannot effect the same decomposition otherwise than very slowly at even the highest temperature of the atmosphere.

XIII. Iron, zinc, tin, antimony appear to be capable of decomposing water. Probably, manganese, and even some other metallic substances are equally capable of accomplishing the same effects. This decomposition is owing to an attraction in the metal for oxigene, stronger than that of oxigene for hydrogen; and in consequence, the oxides of those metals which do not decompose water, are liable to be wholly decomposed by hydrogen. But here we must distinguish among the different degrees of oxidation: for oxide of iron highly oxidated, namely to a brown colour, is partly decomposed by hydrogen, and restored to the state of a black oxide; as iron abstracts oxigene from water only till it be oxidated black: Beyond this state of oxidation, iron is unable to decompose water.

XIV. All metals capable of decomposing water, effect this decomposition much more easily and entirely, when they are aided by the contact of a body that has a great tendency to combine with their oxides. It often happens, even that metals, like other combustible bodies, which would not alone decompose water, become capable of effecting this decomposition, in consequence of the presence of some other substances, which act by a disposing affinity. Thus the presence of acids,
renders

renders almost all metals capable of effecting the decomposition of water.

XV. Metallic oxides have this peculiar in their combinations, that they seem to perform the functions of alkalis or of terrene and alkaline bases, in respect to the acids; although they be, on the other hand, capable of combining with earths and alkalis, as if they were acids. There are indeed fewer of those oxides that incline to act the part of acids, than of those which are fitter for bases to compound salts; and it is observed, in general, that the oxides to which oxigene adheres the most tenaciously, are those which saturate alkalis in the manner of acids;—such as the oxides of antimony, lead, iron, and manganese. It has been already related in the VI. chapter, that there are three metals actually acidifiable.

XVI. The metals cannot be dissolved by the acids, without being previously oxidated. On this account, metallic oxides soluble in acids, dissolve in them slowly and without effervescence: but metals are not soluble in the same menstrua, without movement and effervescence.

XVII. The effervescence produced by the solution of metals, is owing to this cause, that when they absorb the oxigene, they detach it from a principle which then assumes the form of a gas or elastic fluid. This principle proceeds either from water or acids, according as the one or the other of these is the substance decomposed. Sometimes it originates from both these bodies at once; and then they are both decomposed by the metal together.

XVIII. The sulphuric acid thus decomposed by metals, if it be concentrated, yields sulphureous gas: Nitric acid, upon the same occasion yields nitrous gas.

XIX. The sulphuric acid, diluted in water, greatly promoting the decomposition of the water by metals, yields, in this case, gas hydrogene. Solutions of zinc and iron in the aqueous sulphuric acid, act chiefly in this way. The phos-

phosphoric acid exhibits with metals, nearly the same phenomena, as the sulphuric acid.

XX. The nitric acid is not only decomposed by various metals, but even suffers the water in which it is diluted to be decomposed at the same time as itself. In order to this it is enough, that the metal dissolved in the acid, be extremely greedy of oxigene, as is tin. The hydrogen of the water, in this case, combining with the azote of the nitric acid, forms ammoniac; and hence these solutions afford no gas, but are found to contain ammoniacal nitrate. From this it may be understood, how most solutions of white metals in nitric acid, come to afford vapours of ammoniac, when quicklime is cast into them.

XXI. The muriatic acid not being susceptible of decomposition by combustible bodies, can by itself dissolve, but few metallic substances. It acts only on those metals which are so greedy of oxigene, as to decompose the water in which it is diluted. While metals are dissolved by the muriatic acid, there is always a considerable quantity of hydrogenous gas disengaged.

XXII. Not only is the muriatic acid unsusceptible of decomposition by the metals; but it possesses likewise the property of absorbing oxigene from almost all metallic oxides. It passes upon this into the state of oxygenated muriatic acid. To its attraction for oxigene does this metal owe the property it possesses of dissolving metallic oxides with facility: and it is on this account employed successfully to dissolve oxide of iron on which the other acids do not act. If metallic oxides supersaturated with oxigene be dissolved in muriatic acid, the acid effervesces; a part of it then passing into the state of oxygenated muriatic acid gas. If these oxides be oxygenated only to that degree which is requisite for their combination with the acid, they will then dissolve without emotion, and without effervescence, as salt or sugar in water.

XXIII.

XXIII. The boracic and fluoric acids combine but weakly with metallic oxides. They are incapable of dissolving pure metals, because they are not decomposable by these bodies. Yet with water, they produce the oxidation of those metals which have the strongest affinity for oxygen. The same is the case with the carbonic acid, which combines readily with most metallic oxides, and in nature is often found in union with them.

XXIV. The metallic acids are easily decomposed by the most combustible of the metals. They combine readily with the oxides; and in nature, are often found thus combined.

XXV. The vegetable and animal acids, which have radicals composed of hydrogen and carbon, are not decomposed by the metals, but render water highly decomposable by these bodies; and combine in a state of sufficient solidity, with the metallic oxides. Several of them, reduce these oxides to the state of metals.

XXVI. The metallic oxides cannot combine with acids, or remain in union with them, unless in consequence of containing certain determinate proportions of oxygen. Under these proportions, the combination cannot take place; if the due proportions be exceeded, the substances combined, cannot remain in union.

XXVII. Beside this general truth; there is another of the same order, which relates to each metal and each acid in particular. And this is, that the acid and metal cannot remain in union, otherwise than within the often straitened limits of oxidation. There is a determinate proportion of oxygen in the combination of an acid with a metallic oxide.

XXVIII. It is in virtue of this law, that metallic solutions exposed to the air, yield a precipitate, and become turbid, in proportion as the metallic oxide absorbing oxygen from the atmosphere, becomes gradually insoluble in the acid. This is the ratio of those decompositions which are accomplished

plished by the atmosphere, upon most metallic sulphates and nitrates.

XXIX. Nay it often happens, that metallic oxides dissolved in acids, gradually re-act upon these salts, and abstract from them, even in close vessels, and in contact with air, a portion of their oxigene, so that the oxide is soon separated from the acid, and is precipitated to the bottom of the solution.

XXX. Heat is singularly favourable to this successive decomposition of acids by metallic oxides. Thus nitric solutions become turbid, or more and more decomposable, by the action of air and water, if they be at the same time heated. This is particularly remarkable in the case of the nitric solution of mercury.

XXXI. Some metals have so great a tendency to oxidation by acids, that they can neither remain in union with them, nor yet form permanent solutions. Such are, particularly those which possess the property of becoming acid or forming oxides susceptible of combination with alkalis; arsenic, tungsten, molybdena, antimony, tin, iron, &c. Solutions of these metals, in nitric acid especially, are always charged with precipitates, and contain little or no metallic oxide.

XXXII. From these facts it appears, that, in order to form metallic salts, the metallic oxides must remain permanently in union with the acids, without having any tendency to separation. It is also necessary, that care be taken not to augment their affinity for oxigene; and to avoid bringing this principle into contact with them.

XXXIII. Compound metallic salts always, or almost always, possess an excess of acid. They are otherwise, all more or less acrid and corrosive; which shews that almost all metallic oxides have a tendency to become acid.

XXXIV. Those properties of metallic salts which it is of consequence for us to know, may be reduced under the following heads. 1. Form and its varieties; 2. Taste and causticity, more or less considerable; 3. Alteration by light;

4. Fusion, desiccation, decomposition more or less perfect, by caloric; 5. Deliquescence, efflorescence, or decomposition, more or less entire, by means of air; 6. Solubility in water, hot or cold, decomposition more or less thorough, by pure water, &c.; 7. Decomposition by alkalis and earths, the nature of precipitated metallic oxides, the complete precipitation or formation of triple salts, partly alkaline or terrene, and in part metallic; 8. The alteration of precipitated metallic oxides at the moment of their precipitation, either by air, or by the nature of the alkali employed, as in the case of ammoniac; 9. Reciprocal alteration by different acids, decomposition or the contrary, attraction of acids by metallic oxides, the changes of oxides which are distinguishable by their colours; 10. Alteration by the neutral salts, terrene or alkaline, which exhibit either an union without decomposition, or a double decomposition; 11. The reciprocal action of metallic salts upon one another, which displays either a simple union, or a simple change of bases by the acids, or a change in the combination of the oxigene by which the two oxides are precipitated;—the one partially *de-oxidated*; the other *super-oxidated*;—and such for instance, is that useful precipitation of the muriatic solution of gold by the muriatic solution of tin, which furnishes the *purple precipitate of Cassius*; 12. Union with the terrene or alkaline sulphures, and the formation of the different sorts of sulphureous ores.

XXXV. Metallic oxides differ from one another in the degrees of their affinity with acids; so that some of them may be employed to decompose the combinations of others. But above all, the varying affinities of the metals with oxigene, act as the principal cause of the phænomena of the precipitation of metallic solutions: Thus different metals, while they take away the oxigene from other metals dissolved in acids, cause these last, to appear again in the metallic form; as copper, for instance, does with mercury, mercury with silver, iron with copper, zinc with iron, &c. Sometimes the metals do

not detach all the oxigene from the metallic oxides dissolved in the acids. This happens when the precipitating metals do not require all the oxigene of the metals in solution: Thus tin, when precipitating oxide of gold, does not absorb all the oxigene which that oxide contained, but suffers the gold to be precipitated in a particular state of oxidation. Metallic oxides when they thus share the oxigene between them in new proportions, are precipitated with properties that deserve to be better observed, than they have hitherto been.

Application of the general facts in this chapter.

Preparation of all the metallic oxides used in the arts.

Coloured glasses, enamels.

Metallic salts useful in the arts.

Effects of these salts in the arts in which they are employed.

Solutions, and partings of metals.

Precipitation of metallic oxides by earths and alkalis.

These applications are in general so various and so useful, that they cannot be explained in detail, elsewhere than under the particular history of each different metal.

C H A P.

CHAP. X.

FORMATION *and* NATURE of VEGETABLE MATTERS,

I. THOSE matters which compose the texture of vegetables, differ from mineral substances, in being of an order of composition which is more complex, and in being all highly susceptible of decomposition or analysis, while none of them is susceptible of synthesis.

II. Only the substantial contexture of living vegetables, only their vegetative organs—can form those matters which are extracted from them; no instrument of art is capable of imitating those compositions that are continually effected in the organized frames of plants.

III. Although it be with four or five natural substances, caloric, light, water, air, and carbone, extracted from the remains of plants, which have been crumbled down and blended in the soil; that vegetables elaborate all the materials of which their contexture is formed; yet, do we find a wonderful variety of properties in these materials. We may, however reduce all these properties to a certain number of heads, under the name of *the immediate principles of plants*; because these principles are obtained by simple processes, almost entirely

ly

ly mechanical, and by a sort of immediate analysis that produces no alteration of their nature.

IV. These matters, being more or less compound, are lodged in particular organs, or in distinct vessels or cells, &c. Sometimes their seat is in the root or in the stem, in the bark and the leaves all together: At other times, on the contrary, only the flowers, fruits, or seeds, and even some particular parts of these organs, contain the immediate principles. This varying situation of these immediate principles, shews the differences in the organization of the texture to be the cause of that diversity of nature which each of these matters displays.

V. The different place occupied by each of the different materials of vegetables, is often such as to permit us easily to obtain them pure and separate. Where such a distribution takes place, it is sufficient to bruise or open the vessels or cells containing the immediate principles, to open them, or to squeeze out the liquid juices. Nature, by the sole force of vegetation, often presents this separation already effected, on the outside of plants. Thus manna, gum, resins, &c. flow spontaneously. Art is often obliged to separate some of these materials from the confusion in which they are mingled and united with various other matters. The means she employs for this, are usually simple, and easily practised; such as rest, filtration, pressure, washing, distillation by a gentle heat, none of which, alters the substances subjected to it.

VI. Among the materials which compose the frame of vegetable bodies; which are obtained from them by simple means that alter not their nature; and which are either fluid or solid; may be reckoned the following substances.

1. The extractive matter, or extract.
2. The mucous matter, or mucilage.
3. Sugar.
4. Essential salts.

5. Fixed oil.
6. Volatile oil.
7. Aroma.
8. Camphor.
9. Resin.
10. Balsam.
11. Gum resin:
12. Feculum.
13. Gluten.
14. Colouring matter.
15. Gum elastic.
16. The ligneous part.

Beside these sixteen principles, there is found in the analysis of vegetables, a substance resembling the albumen in the animal kingdom. It is probable that there are several other vegetable principles still unknown ; such as the matter which serves for tanning hides, &c.

VII. It is proper, that the reader here fully understand that, when all the facts in the analysis of vegetables, have been reduced to general terms or leading results ; there has been nothing more found in any of all the plants hitherto examined, but the foregoing eighteen substances. These actually compose the contexture and fabric of all known vegetables and when these are separated from any vegetable, that vegetable is very accurately analysed. Yet, we are not to suppose, that these eighteen immediate materials exist in all the different parts of vegetables, or even in every different vegetable. Some plants, out of all their parts, afford not even as many as five or six of these materials ; others contain eight or nine of them ; some yield them all. But, supposing, that we could mix together, and confound, even chemically, all those plants which are subjected to any chemical processes ; the mixture, however seemingly various, would not exhibit more than the sixteen or eighteen substances above enumerated, as

the results of the most exact and elaborate analysis. Vegetables may therefore be said to be formed of those immediate materials.

VIII. Each of the materials above mentioned, possesses peculiar distinctive properties, from among which we must select those which may the best mark their different characters, and discriminate them, one from another. It is not impossible to handle this subject in the manner of the botanists; using but one characteristic or specific phrase, to distinguish each of the materials of which we speak. Although this method have not as yet been either proposed or executed in chemistry; we shall endeavour to give a sketch of it in the subsequent sections; as has been already done in the case of the acids, and the compound salts.

Characters of the immediate materials of vegetables.

IX. *Extractive matter* or *extract*, is a dry, brown matter, somewhat deliquescent, soluble in water; is obtained from the inspissated juices of vegetables, from infusions, and from decoctions evaporated; yields by distillation, an acid, a little ammoniac, and some oil; absorbs oxigene from the atmosphere, and becomes gradually insoluble, in consequence of this absorption; is erroneously regarded as a natural soap; is compounded of carbone, hydrogen, azote, and oxigene, and has always a tendency to absorb more of this last principle, than it contained in its primitive state.

X. *Mucous matter* or *mucilage*, is a glutinous, viscid, insipid substance, which yields pyro-mucous acid by distillation; is soluble in water cold or hot; does not absorb oxigene from the atmosphere; becomes dry and brittle in the form of gum; exists in the roots, the young twigs, and the leaves; is obtained by expression from the bark of trees; connects their fibres together as they grow.

XI. *Sugar*, is of an agreeable, pungent taste, crystallizable, soluble, fermentible, in all respects very like to mucilage, but differing in its susceptibility of fermentation, and of forming alcohol. Mucilage and sugar are both compounds of carbone, hydrogen, and oxygen; and they differ from extract; 1. In having a smaller proportion of hydrogen;—in consequence of which, they do not, like extract, absorb oxygen from the atmosphere: 2. In being destitute of azote, owing to which, they yield no ammoniac by distillation.

XII. *Essential salt*, comprehends the vegetable acids which are in general formed of hydrogen and carbone more copiously oxygenated than in the three foregoing ingredients: and in consequence of this, the addition of oxygen to those ingredients, converts them into acids. The vegetable acids, in whatever number they may be, appear to differ from one another in nothing, save the proportions of their three principles. They are all decomposable by fire, and susceptible of mutual conversion into one another; and in an ultimate analysis, they are all reducible upon the addition of oxygen, to water and carbonic acid. (*See* title VII.)

XIII. *Fixed oil*, was formerly named *fat oil*; is thick, mild, inodorous; burns when volatilized; forms soaps with the caustic alkalis; is mixed with a mucilage which Scheele calls the *mild principle of oils*; is thickened and concreted by the contact of air, and the absorption of oxygen; suffers the same effects from acids and metallic oxides; is compounded of carbone, hydrogen, and a small proportion of oxygen. It differs from the preceding compounds, in possessing a larger proportion of hydrogen. Hence its combustibility, and tendency to change into water and carbonic acid, when it is burnt with a sufficient quantity of air; as in matches which are hollow, and surrounded on all sides with air; forming lamps with an interior current of air.

XIV. *Volatile oil*, called also *essential oil*, and *essence*, is acrid, highly odorate, wholly reducible to vapour at the heat

heat of 212° F.; does not readily combine with alkalis; is inflammable by acids; is inspissated by oxigene to a resin; burns more rapidly than fixed oil, and affords more water; suffers an easier precipitation of its charcoal, which then forms lamp-black.

XV. *Aroma*, otherwise called *spiritus rector*, is a very volatile principle, reducible to vapour by the heat of the atmosphere, and forming a peculiar atmosphere around plants; distillation of the plant on a *balneum mariae*, affords the aroma together with water; sometimes aroma is of an inflammable nature; it presents in other instances, saline properties; it combines with alcohol, fixed oils, vinegar, &c. and in these combinations, forms what in pharmacy is called *distilled waters*; it contributes by its presence to the quantity of volatile oils, that is obtained from plants, and has so great a resemblance to these oils, that the one has been often mistaken for the other. The intimate nature of aroma is not yet exactly known. We begin to think, that it may be a peculiar substance, a solitary principle disengaged from vegetable matters; while these matters themselves are at the same time, entirely reduced to vapour.

XVI. *Campbor*, is a matter now known to exist in many vegetables; is to be reckoned one of their immediate principles; is of a concrete and crystalline form, highly volatile, combustible with smoke, soluble in a great quantity of water, in alcohol, and in æther; exists in many volatile oils; is contained, in purity, in the trunk and leaves of a sort of laurel from which it is ordinarily obtained; is very little known, as to its intimate nature; forms with nitric acid, a new and peculiar acid.

XVII. *Resin*, is a matter, soft or dry, scarcely odorate, combustible, soluble in alcohol, but not in water; scarcely alterable by acids, hardly susceptible of union with alkalis; is obtained from an inspissated volatile oil, from which it seems to differ only in possessing a larger proportion of oxigene.

XVIII. *Balsam*, is resin combined with benzoic acid, more highly odorate than pure resin ; is deprived of its concrete acid by the action of fire and water ; yields this acid to earths and alkalis ; becomes after the loss of the acid, not unlike to resin.

XIX. *Gum-resin*, is a concrete juice, partly soluble in water ; forms with water, a sort of emulsion as well as with vinegar, which has been supposed to be its universal solvent ; is more soluble in alcohol ; does not flow naturally, like resin, from vegetables, but is obtained from their vessels bruised, in the form of a white or variously coloured juice, of a foetid odour, more or less resembling that of garlic.

XX. *Feculum*, is a pulverulent, dry, white, insipid, combustible matter ; yields by distillation, a large proportion of pyro-mucous acid ; is soluble in boiling water ; forms with this liquid, a jelly ; is convertible into oxalic and malic acid by the action of the nitric acid ; exists in all the white and brittle matters of vegetables, particularly in tuberculous roots, and in the grains of gramineous plants ; forms the basis of the nourishment of animals ; and is disposed to become with sufficient rapidity, a component principle of their bodies.

XXI. *Gluten*, is a substance, elastic, ductile, seemingly fibrous or membranous, insoluble in water, slightly soluble in alcohol ; yields by distillation a large proportion of ammoniac ; is putrescible like an animal substance ; takes like animal substances, a yellow colour, upon the contact of nitric acid ; is convertible by nitric acid into oxalic acid ; and existing particularly in the flour of wheat, forms the difference between this and flour of other grains, by giving to the former, the property of composing a paste.

XXII. *Colouring matter*, goes always along with the one or the other of the preceding materials ; appears to vary in its nature,—being sometimes soluble in water, and sometimes subject only to the action of alkalis, oils, or alcohol ;

owes its diversified properties to different quantities of oxigene fixed in it ; has an affinity for combination with alkalines, oxide of tin, &c. is capable of more or less perfect combination with the contexture of bodies animal and vegetable.

XXIII. *Gum-elastic*, resembles gum-resin ; appears to exist in many vegetables ; is remarkable for the ductility and elasticity which it retains, when dry ; affords ammoniac by distillation ; diffuses a foetid odour when burnt ; exists at first in the form of a white, lacteous fluid, and passes into the state of gum elastic by absorbing oxigene from the atmosphere.

XXIV. *The ligneous part, or wood*, a matter that has been hitherto too much neglected by chemists, forms the solid base of all vegetables ; but is by much more copious in those which are hard, than in such as are soft ; has been erroneously regarded as an earth ; is insoluble in water ; affords by distillation that particular acid which is called pyro-ligneous ; contains a great quantity of carbone ; passes into three or four different acid states, by the action of nitric acid ; appears to be the last product of vegetation.

XXV. From what has been above explained concerning the immediate and known materials of vegetables, it follows ; that they are all reducible in a last analysis, to three or four principles, the principles, the primary components of them all ; namely, hydrogene, carbone, oxigene, and in several of the above materials azote ; and that those materials differ from one another only in the diversity of the proportions in which they severally contain the elementary constituents. But, if by simple calculation, we endeavour to find the number of different compounds that may result from such combinations, in all the possible proportions of three or four primary principles, we shall find, that a much greater number of them may easily exist. Yet, as every one of the tertiary or quaternary compositions which form the immediate

materials of vegetables, admits, as it should seem, a certain latitude in the proportions of its principles with which it will still retain its general character of extractive, mucous, oil, acid, resin, &c. &c.; it is natural to infer, that the various proportions of the elementary principles, comprehended within those latitudes, must determine the vast, unmeasurable variety of colour, smell, taste, and consistency, which is well known to distinguish all the materials of vegetables; and which is universally observed in the component parts of those vegetable matters which are in common use for human food, clothing, buildings, &c.

XXVI. Upon the same consideration, it will be easily conceived, that vegetables must differ in the nature and specific properties of their materials, according to the different periods in the advancement of their vegetation; that they can never remain long in the same state; and that the diversified scenes which the periods of germination, foliation, blossoming, fructification, and maturation, the successive æras of vegetable life, exhibit, must necessarily be accompanied and discriminated by internal changes, corresponding to the variation of external appearances. Taste in all its varieties of modification, smell which is no less variable, and those diversities of contexture and consistency which distinguish the different periods in the progress of vegetation, are so many incontestible proofs of this.

XXVII. It is a new advantage derived from the improvements of modern chemistry; that we are now enabled to discern the nature of the materials of plants, which is more complex than that of mineral substances. This acquired knowledge leads us to an estimate of the changes which vegetable matters suffer from different chemical agents. We can no longer say that we are ignorant of the manner in which the destructive agency of fire operates upon vegetable substances: - From the considerations here stated, it appears, that when a vegetable, either entire or in its separate products,
is

is submitted to the action of fire ; the caloric tends to reduce those complex compounds to compounds of a more simple character, by combining their principles, by two and two, in proportions widely different from those in which they before existed together. By heating vegetable products gently, we disengage the hydrogene which burns alone, and leaves a large residue of carbone ; when they are strongly heated, the carbone is disengaged together with the hydrogene ; both burn together in the air ; and the only residue left, is a small portion of earth and salts forming vegetable ashes.

XXVIII. All the immediate principles of vegetables, are then reducible in an ultimate analysis, to three or four primary principles, namely, hydrogene, carbone, oxigene, and a little azote in some of them : This analysis corresponds accurately to the manner in which vegetables are nourished, grow, spread out, and preserve their existence ; since we know that nothing but those simple principles is required to support vegetation :—We have therefore nothing farther to investigate, but the manner in which plants appropriate to themselves these elements, and the means by which they combine by their organic functions ;—in order to enable us to form by compositions, those substances of which the properties have been explained.

XXIX. There seems to be no doubt but that water affords the hydrogene of vegetables ; that they decompose water in their leaves, aided by the contact of solar light ; that they absorb the hydrogene of the decomposition, which is fixed in them, in the state of oil, or extract, or mucilage, &c.; and that they evolve the oxigene, of which a great part is fused by light and caloric, and disengaged into the state of vital air. But, a portion of the oxigene of the water thus decomposed, is at the same time fixed in the texture of the vegetable, and is retained there, particularly by the attraction of the carbone.

XXX.

XXX. It is not so easy to give an account of the origin of the carbone which exists in vegetables. Some naturalists think that vegetables decompose carbonic acid at the same time as water, and absorb the carbone. This assertion is without proof; although it has gained new authority since the discovery of the decomposition by phosphorus of the carbonic acid combined with soda. Other chemists think, that vegetable earth, *humus*, dunghills, and especially water from dunghills afford carbone divided, or even dissolved in water; that plants absorb this principle by their roots, and do not abstract it from carbonic acid. According to this opinion, dung affords nothing but carbone; and the water of the dunghill is but a saturated solution of this principle. To these data must the chemical theory of vegetation be confined, until it shall be enlarged by farther investigation and experiment.

Application of the general truths in the tenth chapter.

These general truths are applicable to a very great variety of cases in nature and the arts. They respect agriculture, rural œconomy, pharmacy, materia medica, and all those arts which are employed upon vegetable substances. The following are a few of the most important cases of their application.

Germination.

The unfolding of the leaves of vegetables.

The blossoming of vegetables.

Fruetification.

The ripening of fruits and grains.

The successive formation of gum, extract, oil, resin, salts, sugar, colouring matter, wood, in the different periods of the life of a plant.

The growth of the ligneous substance, of the bark, &c.

Pharmaceutical

Pharmaceutical preparations of juices, extracts, essential salts, mucilages, oils, resins, gum-resins, aromatic waters, &c.

The arts of the sugar-boiler, the confectioner, the miller, the baker, the starch-maker, the vine-dresser, the brewer, the distiller, the varnisher, the dyer, the paper-maker, the indigo-maker, the colour-man, the flax-dresser, the oil-man, the soap-boiler, the perfumer, the charcoal-burner, &c.

CHAP.

CHAP. XI.

Of the FORMATION and the NATURE of ANIMAL SUBSTANCES; THEORY of ANIMALIZATION.

IT is a certain truth, that animals cannot support their existence, without the use of vegetables. In natural history, it has long been said, that vegetables are formed from minerals, animals from vegetables. But if this truth have been long known; yet the manner in which these bodies are mutually changed one into another, remains still unascertained. This however is the grand subject upon which, above all others, the labours of the chemist ought to be employed. This problem once solved, we shall obtain an exact knowledge of every thing respecting the animal œconomy. Modern discoveries afford already a variety of results which must be useful in these important researches.

II. The surest means for resolving this problem, is undoubtedly, first, to discriminate accurately between the different animal substances; to compare them with the peculiar matters of the vegetable kingdom; and carefully to examine the difference or resemblance subsisting between the two classes. There is no doubt, but that, if these differences were once well known; we might then discover the causes to which *they are owing.*

III.

III. Collecting the results of all the analyses that have been lately made of the blood and humours, and of the solid parts of the human body which are evidently formed by the concretion of the fluids ; we shall find the most striking differences between animal and vegetable substances, to be the following.

A. The property in animal substances of affording ammoniac and foetid products, when acted upon by fire.

B. Their property of putrefying more easily, and more rapidly, and of emitting an odour much more noisome.

C. Their yielding much more of gas azote, when acted upon by nitric acid.

D. Their contributing in a singular manner to the formation of nitric acid.

IV. All these differences seem to depend upon the existence of a particular principle which is azote, in much greater abundance in animal than in vegetable bodies. It should seem then, that the addition of azote to vegetables, might fully assimilate their nature to that of animal matters.

V. It is however to be farther observed, that to these primary and *capital distinctions* between animal and vegetable substances, there are other particular phenomena to be added ; the influence of which, although, no doubt smaller upon the animal compound ; is yet, not to be neglected. Such, among others, is the presence of the phosphoric acid, and of different phosphates, particularly phosphates of soda, lime, and ammoniac, in animal humours. To these salts is owing the peculiar quality, and the almost incombustible character of the coal of animal matters.

VI. That particular principle which is so copious in these substances, and which especially establishes the grand distinction between them and vegetable substances, namely, azote ; appears therefore to be the efficient cause of the properties by which animal matters are distinguished ; and particularly of that

gase, such as man, birds, and quadrupeds have. It likewise explains the origin of some diseases of the liver, particularly of biliary stones or concretions.

XI. The *grease*, or *fat*, is a sort of oleaginous matter formed at the extremities of the arteries, at the farthest possible distance from the centre of animal heat and motion; forms a sort of reservoir, in which that large quantity of hydrogen is fixed, which the lungs are unable to evacuate; is an oil combined with a considerable proportion of oxygen, and containing, besides, sebacic acid. To consider fat in this light, is, a point singularly striking in the chemical physiology of animals.

XII. *Urine* is an excrementitious fluid, more or less coloured, acrid and saline, remarkable for the great quantity of uncombined phosphoric acid, of phosphate of soda, of ammoniac and lime which it contains; still more remarkable for containing a peculiar acid which has not as yet been found in the rest of the animal humours; and which is now named *litbic acid*; because it forms the base of calculi in the reins or bladder, in the disease called *litbifis*.

Some of the most valuable discoveries of chemistry respect the urine; medicine has still discoveries to make concerning this excrementitious fluid. Considering it, in the first instance, as a lixivium intended by Nature, to convey out of the body, a great quantity of saline matters which would otherwise prove noxious to the vital functions: we are hence led to perceive, in the next place, that, in the urinous evacuation, the proportion of the principles will vary with the state of the body, and thus will become a sort of measure indicating by its varying modifications, the health or sickness of the vital frame. Physicians have already successfully begun their observations upon this matter. The urine is to be regarded as containing always the matter of concretions in the reins or bladder. These concretions require to their formation, nothing but the detention of this matter, a longer time than

Nature has designed, in its proper organs, on an incipient solid on which these saline concretions may be from time to time deposited. The proportions of the different principles is various; and especially the naked acids which it contains, are to be carefully observed; as is likewise the phosphate of lime suspended in it; both which vary strangely in diseases of the joints, of the osseotubercles, and of the bones. Of these facts accurately noted, skilful observers may hereafter make happy use in medicine; deriving from them, new means of knowing the nature of such distempers, of ascertaining their progress, and perhaps of accomplishing their cure.

XIII. We can say little concerning the other animal fluids, such as the humour that is transpired from the pores, sweat, the gastric juice, the cerumen of the ears, the saliva, the humours of the eyes, the mucus of the nose, the seminal fluid, &c. because all these fluids have hitherto been but little examined. They have, every one, no doubt, a particular composition, different in each of them, from all the rest, in various points, especially in the proportion of their principles. Some of these principles being somewhat better known by modern experiments, than the rest, exhibit a combination of a particular sacilage with water, pure soda, phosphate of lime, and phosphate of soda. Such are tears, the mucus of the nose, and the spermatic juice. Of these, the two former possess the property of becoming thick by the contact of air, and the absorption of oxygen; which probably constitutes the maturity of the humours in the brain and lungs in cases of catarrh. The seminal fluid exhibits the singular phenomenon of the crystallization of phosphate of lime, hitherto unknown in other instances.

XIV. Considering the whole of those solid matters which compose the varied constitution of the different organs of animals; we may divide the substances that form them into three principal genera. The first of these will comprehend the albumen; the second, the gluten or gelatinous matter;

the third, the fibrina or fibrous matter. Of these bodies two have already been noticed in the VIII. section of this chapter, under the article, *Blood*. We shall here briefly mention those permanent phenomena which are to be considered as the characters of each of the genera.

FIRST GENUS.

Albumen is concrescible by heat, by acids, by oxides, and in general by oxygen whenever it is concrete or nearly concrete; is soluble by alkalis; exists, more or less condensed or oxygenated, and wrought into consistency, in the membranes, the tendons, the gristles, and in general, in all white animal matters.

SECOND GENUS.

The *gluten*, partakes of the solidity of the former genus in most of the white organs; is susceptible of easy separation and solution by boiling water, to which when cooled, it gives the form of a jelly. As it forms the base, or the larger proportion in all the white organs in general; those are susceptible of more or less perfect solution in boiling water, and form transparent jellies by the refrigeration of their solutions.

THIRD GENUS.

The *fibrina* is insoluble in water at any temperature; is soluble in acids; contains a large proportion of azote; is condensed, concreted, and organized in muscular flesh, which may be regarded as the reservoir of all the fibrina contained in the blood. Considering the muscles as the secretory organs of this fibrous matter of the blood; we may examine and observe all the modifications of the quantity or proportion in which it is fixed in those organs; and may attend particularly to that exclusion of it, which they seem to exact in certain morbid states of the body, in old age, &c.

XV. These three matters, albumen, gluten, and fibrina, in concretions, in combinations of two and two, or three and three

three together, especially if they be in different proportions, compose all the solids of animal bodies. They are separated from one another by an easy and simple analysis. They form also various animal fluids, particularly albumen. Only, in these fluids, they contain less oxigene, more water, and are united with acids, neutral salts, &c. It is to be observed, that the gluten is as scanty in the fluids, as it is copious in the solids : and seems therefore to owe its gelatinous nature to that elaboration which it undergoes, when passing from a fluid to a solid state. Albumen artificially dissolved by acids, assumes properties analogous to those of the gluten.

XVI. The solid, osseous substance of animals, is of another order of composition. A large quantity of an almost insoluble terrene salt (phosphate of lime) is deposited in the primitive texture or parenchyma of the bones. This is the whole mystery of the structure and composition of these organs. In consequence of this, bones afford a jelly by decoction in water, and yield by distillation, a large proportion of oil and ammoniac. Bones once well calcined or burnt, are after this, nothing more than calcareous phosphate, mixed with some portions of carbonate, muriate, and phosphate of soda.

XVII. When these preceding animal matters, especially when the white fluids inspissated, or the white organs, are heated with nitric acid ; there is disengaged from them, a quantity, greater or smaller, of gas azote, and of Prussic acid gas, which appears to be nothing else than a combination of azote, hydrogen, and carbone, with a small proportion of oxigene. Of this product, the gluten yields the least ; the albumen, more ; the fibrine, the most. In proportion as this new combination of the principles of animal matters, takes place by means of the nitric acid ; those matters seem to return to their original state of vegetable substances ; from which, as has been observed, they differ materially in nothing but in possessing a quantity of azote, in having different proportions of carbone and hydrogen, and in the greater complexity of the number

of the combined materials into which the primary elements are formed in the animal compound. Instead of being ternary compounds, as vegetables are, animal matters are quaternary compounds, or even more complex. Azote is the fourth primary principle of animal matters, which they possess in addition to the hydrogen, carbone, and oxygen of vegetables.

XVIII. Thus the conversion of vegetable matters into animal matters, which consists merely in the fixation or addition of azote; is to be considered as the principal phenomenon of animalization. This alone explains the principal difficulties of that phenomenon: and when the mechanism provided for the addition of this azote shall have become sufficiently known; most of the functions of the animal economy, which contribute to, or depend upon it, will then also be known.

XIX. What is already known concerning this last subject, is limited to the following particulars. It is not so much by the addition of a new quantity, as by the removal of other principles in consequence of which the proportion of the azote originally present, becomes greater, that this phenomenon is accomplished. In respiration, the blood exhales a great quantity of hydrogen and carbone; the last either simply dissolved in gas hydrogen, or else reduced to carbonic acid in the very act of circulation, and in the vascular system, as some modern physiologists have conceived. In the cavities of the *bronchia* during the act of respiration, and by means of this act, the hydrogen forms water which is exhaled in expiration. A portion of the oxygen appears to be at the same time fixed in the blood in the lungs; and circulating with this fluid through the vessels, it is gradually combined with the carbone, so as to form that carbonic acid which is disengaged from the venous blood in the breast. It is easily conceived, that a large quantity of hydrogen and carbone being thus disengaged by respiration, the proportion of the azote must be by the same act increased. The investigation of the mechanism of the other functions—

functions, will no doubt lead to new discoveries more important than these which are here detailed. What has been done within these last few years, naturally leads us to expect, that much more may within no long time be done. The analogy of action which has been discovered to subsist between digestion, respiration, the circulation, and transpiration, has begun to establish upon new views much more solid than those which were formerly entertained,—a system of animal physiology that promises a rich harvest of discoveries and utilities. No doubt, by the assiduous investigation of the phenomena of digestion and of growth in young animals, we shall at length succeed so far as to erect upon those bases, a structure equally new and solid. Every thing is ready for this grand series of researches: Several philosophers have already entered upon it: A new ardour springing from the new conceptions which they have formed, stimulates and encourages those who are engaged in this department of physics. The path which they have opened up, cannot fail to conduct them to results the most precise and accurate; exceeding in these qualities, all that has been hitherto advanced concerning the functions which constitute animal life.

Application of these propositions.

The functions of the animal œconomy; and particularly,

Respiration;

Digestion;

Hematosis, or the formation of blood;

Transpiration;

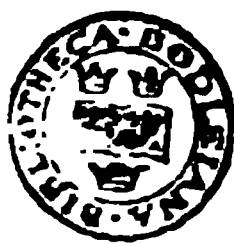
The secretion of the bile;

Osification and osteogony;

Nutrition;

Maladies arising from the corruption of the humours, &c.

Animal concretions;



The action of various medicines upon the human
&c. ;

Those arts which are employed in the treatment of
animal matters ; particularly, the arts of the tanner,
the currier, the maker of glues, the maker of
cords ; the arts of extracting oils, and of man-
ufacturing into useful implements, the horns,
hooves, &c. of animals.

CHAP. XII.

Of the SPONTANEOUS DESTRUCTION of ANIMAL and VEGETABLE MATTERS.

I. WHEN vegetables and animals are deprived of life, or when their products are abstracted from the individuals to which they belonged ; movements are then excited in them, which destroy their contexture, and alter their composition. These movements form different sorts of fermentations. The purpose of Nature in exciting them, is evidently to render more simple, those compounds which are formed by vegetation and animalization ; so that they may enter readily into new combinations of different kinds. That matter which has been for a time employed in forming the bodies of vegetables and animals, is, after their functions are ended, to pass through other combinations, and to enter into the composition of other bodies.

II. From this definition of fermentation in general, it appears, that the species of fermentation must be as various as those of the animal and vegetable substances that are affected by it. But, of these, a number pass through the same process, while they are reduced to greater simplicity of composition ; and in reference to this, all the variety of fermentations may be reduced,

to three leading species; vinous fermentation, acetous fermentation, putrid fermentation.

III. *Vinous fermentation*, as its name indicates, is fermentation which produces wine or alcohol. The matter subject to it, is saccharine matter, diluted in a certain quantity of water, and mixed with some third matter, vegetable or animal, extract, salt, feculum, &c.; for it is now ascertained, that sugar and water alone are not susceptible of vinous fermentation. The saccharine substance is so copious, and universally diffused through all vegetable and even animal matters; that there is a prodigious number of bodies capable of affording wine or forming alcohol. All sweet and saccharine fruits when reduced to a pulp, and particularly their expressed juices, undergo an internal emotion at a temperature not under 66° F. if they be at the same time, in a large quantity and neither too thick, nor too liquid. Hence that vast quantity of different wines which we possess; reckoning with the decoctions of germinating grains, in which the saccharine part is developed by germination; and even the vinous liquors made with milk, honey, blood, &c.

IV. *Vinous fermentation* discovers itself in saccharine juices by an increase of their bulk, the formation of a copious foam that covers their surface, rise of temperature, the disengagement of a great deal of carbonic acid, the conversion of a sweet liquor into an acid, hot, and pungent fluid.

V. The cause of this fermentation appears to depend on the decomposition of water, of whose oxigene, a large portion is brought into union with the carbone of the sugar, which burns, and so converts it into carbonic acid. At the same time, the hydrogen of the water, is brought into contact with the decarbonated sugar, and by combination with it, forms alcohol. Alcohol may be defined to be *sugar, deprived of a portion of its carbone, the place of which is supplied by a certain proportion of hydrogen*. This theory explains both the formation of the carbonic acid which is disengaged during
vin

vinous fermentation; and the formation of alcohol, with all the properties of this new product.

VI. Pure alcohol is a white liquid, of a strong smell, of an hot and acrid taste, convertible into vapour at the temperature of 176° F. inflammable at any temperature; affords, when burning, a large proportion of water and carbonic acid; disales no smoke during its combustion; is miscible in any proportion with water, expelling the air and a portion of caloric, while the combination takes place; dissolves the pure or caustic alkalis; decomposes the acids, and by this decomposition, is itself converted into æther; dissolves deliquescent neutral salts, and many metallic salts; detaches from vegetables their volatile oil, aroma, resin, balsam, a part of their gum-resin, and several colouring matters; is by means of all its properties, useful in many operations of the arts.

VII. The formation of alcohol is effected by the destruction of a principle of vegetables; the saccharine matter suffering upon this occasion, a decomposition by which it is reduced to greater simplicity. Vinous or alcoholic fermentation is therefore a commencement of the destruction of those principles which are formed by vegetation. It may be considered as an interior emotion, designed by Nature, to simplify the order of composition which vegetable substances exhibit.

VIII. Acid or acetous fermentation is the second natural movement by which vegetable compounds are reduced to a more simple state of composition. This fermentation which produces vinegar, can take place only in liquors that have already undergone vinous fermentation. It has been remarked that the contact of air is necessary for the production of vinegar. We have even seen air to be absorbed by wine turning sour; and it appears, that a certain proportion of oxigene from the atmosphere is necessary to the formation of acetous acid.

IX. There, are no doubt, other sorts of fermentation analogous to that by which vinegar is formed; but of such fermentations the products are not yet well known. Such, for instance,

stance, is that which takes place in water mixed with starch which is called the starch-maker's sour water. Such likewise is that of soured bread, soured cabbages, and sour liquors. All these changes are to be considered as modes of decomposition which serve to simplify the complicated combinations of vegetables.

X. Lastly, After that the liquids of vegetables, or their solids moistened, have passed into the acid state; their decomposition continuing under favourable circumstances; that is say, in a mild or hot temperature, exposed to the air, or contact with water; conducts them to a putrefaction in which they are in the end volatilized, in the form of gas, to most of their principles. There is disengaged, water, carbonic acid, carbonated gas hydrogen, sulphurated gas hydrogen, volatile oil in vapour, and sometimes, even gas azote and ammoniac. Nothing remains, after this, but a brown black residue, known by the name of *mould*, consisting of carbon that is somewhat fat and oily, and from which water extracts several saline substances, and a small portion of extractive matter.

XI. Nature, when organizing animals, and forming the humours and solids by complex compositions; has mingled their composition a germ of destruction, which unfolds itself after the death of the individual.

This destruction is effected by that movement which is called *putrefaction*. It consists in a sort of fermentation, in a decomposition of those liquid or solid substances in which it takes place. The order of the composition of animal matter is more complex than that of vegetables, and renders them much more susceptible of putrid decomposition.

XII. Animal matters being compounded of hydrogen, carbon, oxygen, and azote; and having often superadded to these principles, portions of sulphur, phosphorus, &c.; when they are deprived of that motion and continual renovation which constitute animal life; are soon altered by the more fix mutual attractions of their principles, which tend to combine
together

together, by two and two. This re-action produces binary compounds, such as carbonic acid, nitric acid, ammoniac, carbonated gas hydrogen; which are by degrees evolved into the atmosphere; and as they are evolved, proportionally diminish the bulk of the animal matters from which they are separated. It is in this manner, and in consequence of natural decomposition; that animal matters are seen to become soft, to change their colour and smell, to lose their structure and form, to diffuse through the atmosphere, vapours and gases which are there dissolved, and are destined to convey into other bodies, particularly into vegetables, the materials necessary to their formation.

XIII. All the phenomena of the putrefaction of animal matters, depend upon the mechanism which has been explained: The union of hydrogen and azote produces ammoniac; which has been regarded as the principal product of putrefaction. The combination of carbone with oxigene accounts for the formation and disengagement of carbonic acid; in which all the mysteries of putrefaction were supposed to consist, about the time of the first discovery of the gases. The nitric acid, to the formation of which, animal matters powerfully contribute in artificial nitre-works,—is produced by the union of azote with oxigene. A certain quantity of gas hydrogen is disengaged, and involves with it some portions of carbone, sulphur, and even phosphorus. Hence that noisome smell, which is so exceedingly various, and hence, perhaps, the phosphorescence of all putrefying animal substances:

XIV. When all these volatile principles are combined two and two together, and dispersed through the atmosphere, there remains no residue, but a portion of carbone, united or mixed with fixed saline substances, such as phosphate of soda, and phosphate of lime. These residues form a sort of *mould* that is called *animal earth*; which often retains in it a little sulphurated and carbonated hydrogenous gas, a little fat, and some ~~extract~~; and in which vegetables find abundance of those principles

principles which are fit for the formation of their materials. Hence is it that this animal residue, when the previous putrefaction is entirely past, forms an excellent species of manure.

XV. There is a certain quantity of water necessary to this putrid decomposition of animal matters. It affords the oxigene requisite to the composition of the carbonic acid and nitric acid. It contributes remarkably to excite the putrefactive emotions, by means of the attractions of its oxigene. The hydrogene, too, evolved from the water, must doubtless contribute greatly to the formation of the ammoniac: for it is a well known fact, that, when animal matters are diluted in a large quantity of water, they afford abundance of ammoniac, during their decomposition.

XVI. Putrefaction, consisting in a series of peculiar attractions, is modified in many different ways by all its exterior circumstances, such as temperature, the medium in which animal matters are placed, the state of the atmosphere, as more or less ponderous, dry or humid, &c. It is thus that carcasses buried in the earth, immersed in water, or suspended in air, undergo a diversity of changes to which their mass, their quantity, and the vicinity of other bodies, as well as all the varied properties of the three media here mentioned, continually give new and different forms.

XVII. Proofs of the truth of this assertion, occur in what happens to dead bodies, interred either separately, each by itself,—or in heaps together. The former being surrounded by a great quantity of earth, are soon destroyed by putrefaction, the æriform or liquid products of which are absorbed by the surrounding earth, or by the atmosphere. Bodies buried in heaps together, not having around them the same sort of earthen or atmospheric receiver, remain long undestroyed; their animal matter is entirely converted into ammoniac and concrete oil: and this oil with the volatile alkali, forms that saponaceous matter which has been found in the earth of burying grounds, in which there has been too great a number of corpses deposited.

XVIII.

XVIII. In water, different phenomena attend the destruction of animal matters: As fast as the new products are formed, the water dissolves, and conveys them into the air. A continued moisture at a temperature, a few degrees above 32° F. favours the putrefaction of these matters, and their solution into gas. A dry, hot air, on the contrary, volatilizing the water, dries and hardens the animal bodies, almost as well as the dry burning sand does in Egypt, that land of mummies.

XIX. Although all the circumstances of putrefaction, and all the varieties, almost innumerable, of the phenomena which they exhibit; have not been as yet either discovered or described; it is however acknowledged, that all those phenomena must be limited to the conversion of the more complex compounds into others of a simpler composition; which Nature then employs in new combinations forming the materials of other complex bodies. She had only lent them for a time to animals and vegetables. She carries on a perpetual circulation of compositions and decompositions; which display her power, and evince her fecundity, at the same time while they shew a plan of action, equally grand and simple in its operations.

Application of the propositions in this last chapter.

Beside all the objects mentioned at the end of the two chapters immediately foregoing, to which the articles in this chapter afford almost direct applications; the principles, particularly explained in this chapter, are likewise susceptible of the following applications.

The preservation of all substances extracted from vegetables;

The different spontaneous alterations which vegetables undergo; acetous fermentation, vinous fermentation, &c;

The

The products of these alterations, often employed in the arts ;

The production of ammoniac and nitric acid ;

The influence of putrefaction in the different regions of living bodies ;

The infection, and other evils, produced by the vapours of putrefied matters ;

The theory of the situation and management of hospitals, drains, sinks, lay-stalls, common-sewers, cemeteries, &c.

ELEMENTS

THE PHILOSOPHY

OF

CHEMISTRY.

C O N T E N T S

OF THE

PHILOSOPHY OF CHEMISTRY.

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ADVERTISEMENT.

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SOON after entering upon the study of chemistry, I was induced, by the persuasion of a Bookseller, to undertake a translation of FOURCROY'S ELEMENTS OF CHEMISTRY, from the *third edition* of the original work, then newly published. In that edition, the author had, for the first time, adopted the *opinions* and the *language* of the NEW THEORY, which had been lately suggested by the important discoveries of the illustrious and lamented Lavoisier. The new language of that theory was in the translation to be accommodated to the structure and analogy of the English tongue; and other peculiar difficulties also concurred, to render the task in which I had engaged, extremely arduous. I acquitted myself of it, as well as I could. My translation has been called for, sold, and read; till the edition then printed, has been exhausted; and till a *fourth Edition* of the *Original Work*, with *alterations* and *additions* by the *Author*, has been received in this

I, in the mean time, continued to pursue my chemical studies, with that fondness, which the sublimity of the general truths of this science, the endless diversity of the phenomena that fall under its laws, and its unrivalled utility for enlightening the arts of life, are well adapted to excite in every ingenuous mind. With great pleasure, therefore, did I listen to the request of the present Publishers, when they informed me of their intention to reprint my translation of Fourcroy's work; and desired that I would revise and correct it for the press; collating it with the new edition of the *original*; altering what the author had altered; and adding whatever additions he should appear to have made. I was pleased to have a new opportunity presented to me, of humbly doing somewhat more to promote the knowledge of a science in which I delighted. I was not less pleased with the opportunity of correcting some *erroneous numbers*, some *awkward expressions*, some *unnecessarily paraphrastic passages*, and *others* in which an *attempt to concentrate* the meaning of the author, had *produced obscurity*, in that translation of this excellent system of chemistry, which I was now to revise and improve.

What I thus again undertook, I have executed; and the work is here presented to the public. I have carefully revised my former translation, and have corrected whatever I found to be inaccurate, obscure,

obscure, or coarsely inelegant in it. I have collated it with the new edition of the original work, and have adopted all the alterations and additions of the author. I have even added a considerable number of *Notes*, correcting errors, illustrating obscurities, or supplying deficiencies of important information, in FOURCROY's text.

These NOTES it had been easy for me to enlarge to almost any indefinite bulk and number. But, I reflected, that notes, however they may variegate the pages of a book, are too often overlooked, in the reading, especially by the young student; or, if perused, serve too often for no other purpose in the perusal, except to distract the attention of the reader, and to interrupt to his mind the author's chain of reasoning or narration. After reading an elementary treatise, exhibiting rather the whole system of the general principles of any science, than all the detail of minute facts comprehended under those principles; let the student no longer plod among compilations, but trace the science which he studies, through the writings of those authors alone, who have enriched it with original and uncontroverted theories, or with new observations and experiments. It were perhaps desirable, that even this elaborate and comprehensive work of FOURCROY, should be condensed to one half of its present bulk, rather than clogged and burthened with endless additions. I have given such a pro-

portion of *notes* as seemed indispensibly requisite; but none for the sake of useless ostentation.

I have always thought that the physical sciences ought not to reject the advantages of purity, perspicuity, and precision of style, any more than the moral sciences and the fine arts. It is piteous to see, what a Babylonish jargon the translation of many books of chemistry, natural history, and natural philosophy, from foreign tongues, has introduced into the English language. The technical phraseology of every art and science *must* become it, because absolutely necessary to its accurate exposition. But foreign words unnecessarily intermingled with English idioms, and English words in the construction and arrangement of a foreign language, can never serve the interests of science, and ought not to be employed in the enunciation of it. Chemistry, since it has aspired above the laboratory of the alchemist, and the shop of the apothecary, ought to be arrayed in those simple, yet dignified and elegant graces of writing, which are suitable to its philosophical character. I have therefore laboured at once to make Fourcroy speak pure, perspicuous, intelligible English; and to preserve strictly the propriety, the peculiar phraseology of the science, and of the new theory. How far my endeavours may have been in this successful, it is not for me to decide.

In so extensive a work, executed in haste, many little inaccuracies will, no doubt, still remain.

A new translation of Fourcroy's **PHILOSOPHY OF CHEMISTRY** is prefixed to the first volume of this translation of the **ELEMENTS, &c.** It cannot fail to be useful as a **SYLLABUS** of all the general doctrines of the science, and as a sort of introduction to the larger work.

R. HERON.

PREFACE TO THE FOURTH EDITION

BY THE

A U T H O R.

NO science was ever more generally or
gerly cultivated than chemistry has
ring these last twelve or fifteen years: No sci
made such rapid progress in so short a time
circumstances render a fourth edition of this
cessary. The second edition having been al
tirely sold off in the space of eighteen mont
consequently less time for improving it in a
tion, than I had for improving the first in it.
edition, therefore, the work was enlarged o
one additional volume: but in the second
been added. Every elementary work, as
through successive editions, must at length
period at which the judgement of the learned
cerning, will declare farther additions unnecess
after which, review and careful corrections w
only proper means of improving it. I am of
that in the third edition my work reached the
An account of the new discoveries since the y
would not have added greatly to the bulk of
lumes: But by the advice of some judicious

and in consequence of understanding that beginners found some difficulties in the perusal of this work, I was induced to alter and enlarge some chapters in the history of saline matters, of some of the metals, and of several of the immediate principles of vegetable and animal bodies. The additions made, in this *fourth edition*, to the contents of the third, are so few, as, all together, to enlarge the work but by a few pages in the compass of the whole five volumes.

When I composed, in the years 1780 and 1781, an abstract of the fundamental facts of this science, to serve as a syllabus to my lectures; I followed the same plan which I had before adopted in my lectures, and of which some years' experience had taught me the advantages. The unexpected success of that work induced me to follow the same plan in the second edition, published about seven years since. The encouragement which the second and third editions have received from the proficients in chemistry and the friends of science; and the preference which the rapid sale and the various translations authorize me to say, has been given to my work as an elementary book on chemistry through all Europe; induce me still to adhere to the same plan which was laid down in the first edition. To alter my arrangement would have been in some measure to form a new work: yet I know not but it *might* be altered without any impropriety. Perhaps, the more correct knowledge which has been gained since the publication of my first edition; the more conclusive reasonings; and the more accurate and numerous experiments with which chemistry has, since that time, been enriched; would render it advantageous to arrange the

elements of the science in an order somewhat different: To place, for instance, the history of all combustible bodies, sulphur, coal, metals, &c. before that of acids; most of which salts are either burnt bodies, or compounds of combustible bodies. This would be to proceed from simple to compound: the acids of one kingdom would not then be separated from those of the other two kingdoms: only the differences between the principles of organic bodies and those of minerals, would be treated of in distinct chapters. I have marked out a sketch of this method in my Treatise on the Elements of Chemistry, intended for the use of the ladies, and the pupils of the Royal Veterinarian School*.

But although, in the present state of chemistry, this last mentioned arrangement of its elements may be preferable; yet that which I at first adopted, and still adhere to, is not without its advantages. It requires somewhat more particular attention from the student: but even in this instance, it is peculiarly favourable to his improvement. It exhibits the same facts in two different lights; it recalls the mind a second time to truths, which have been already submitted to its view; and thus impresses more distinct ideas of the different phenomena, and of their mutual relations.

With respect to the theory laid down in these elements, the third edition was essentially different from the two former editions. In them, I appeared only as the historian of the different opinions which had prevailed among chemists. But, in the third edition, though I

* School for the Medicine of Animals, which was established at Alfort, near Paris.

I still maintained the same impartiality, and gave an account of the principal theories which have been proposed; yet I espoused a side, and declared myself an entire convert to that doctrine which has received from some philosophers the name of *pneumatic* or *antiphlogistic*. In this fourth edition, my opinion is still more strongly expressed in favour of the *pneumatic theory*; because I am still more entirely convinced of its truth. I flatter myself, that every unprejudiced person who shall carefully peruse these elements, will find that this theory differs essentially from all others that have been hitherto proposed; as it takes nothing upon supposition, admits no hypothetic principle, and consists only in a fair detail of facts. I may even venture to say, that those philosophers who have not yet adopted this doctrine; particularly those who have combated it in some instances with rather too much warmth, have not fully comprehended our meaning. They do not see that the ground of our opinions, the foundation on which our principles stand, is totally different from those of other theories which occur in the study of physics. We only deduce plain inferences from a great variety of facts: we admit nothing not demonstrated by experiments: and as we reject every hypothesis, we cannot possibly commit such blunders as those into which the authors of all former systems of physics have fallen. Either I, and those other modern chemists who have produced so many ingenious discoveries, are grossly mistaken; or the rising generation of students, who are taught to reason in a very different manner from their predecessors, will renounce, as we have presumed to do, the hypotheses which have been so much agitated in the schools,

schools, and will confine themselves to the results of fair experiments.

The modern *theory of chemistry*, which is denominated the *pneumatic*, and which denies the existence of phlogiston, is daily gaining new converts; and is already so generally received, that three fourths of the students, and especially of the teachers of chemistry, may now be reckoned among its adherents. The two most eminent chemists in Europe, Dr. BLACK, and Mr. KIRWAN, after examining, with the utmost care, the new principles of the French chemist, and after contending against them for the space of ten years; have, at last, with the candour becoming men of real genius and enlarged minds, frankly adopted them. "At last," writes Mr. Kirwan to M. Berthollet, in a letter dated on the 26th of January last, "I lay down my arms, and abandon the cause of phlogiston. I clearly see, that there is no unequivocal experiment to prove the production of fixed air from pure inflammable air. This being so, it is impossible to maintain the doctrine of phlogiston with respect to metals, sulphur, &c. Without decisive experiments we cannot form a system, in opposition to positive facts. I shall myself compose a refutation of my own essay on phlogiston."

Dr. BLACK thus expresses himself, in a letter to M. Lavoisier:

"You have been informed of my endeavouring to explain to my pupils the facts and principles of the new system which you have been so fortunate as to discover, and which I begin to recommend, as being more simple, more uniform, and more consistent."

“ with facts, than the old theory. And how could I
“ do otherwise? The many skillful experiments which
“ you have made in the great way, have been profe-
“ cuted through all their changing phenomena with
“ such assiduous care, and such scrupulous attention,
“ that nothing can be more satisfactory than the proofs
“ to which they have conducted you. The system
“ which you have founded upon your facts, is so close-
“ ly connected with them, so simple, and so easily
“ intelligible, that it must daily obtain increasing ap-
“ probation; and cannot fail to be adopted by a great
“ many chemists who have been long accustomed to
“ the old system. You must not hope to convince
“ every person. You well know, that habit enslaves
“ the minds of most men, and makes them believe
“ and reverence the greatest absurdities. I must con-
“ fess to you, I myself have felt its influence. Hav-
“ ing been accustomed for thirty years to believe and
“ teach the doctrine of phlogiston, as it was under-
“ stood before the discovery of your system; I long
“ felt a degree of dislike to the new system, which re-
“ presented that as an absurdity, which I had regard-
“ ed as scientific truth. But that dislike, as it arose
“ only from the force of habit, has been gradually di-
“ minished and overcome by the clearness of your de-
“ monstration, and the solidity of your plan. Al-
“ though there be still some particular facts of which
“ the explanation seems difficult, and scarce satisfacto-
“ ry; I am, however, convinced, that your doctrine
“ is infinitely better founded than the old theory; and,
“ in this respect, cannot suffer by a comparison with it.
“ But, if the power of habit still hinder some old che-

“ mists

“ mists from approving your ideas ; the *young* cannot
“ be *influenced* by the same circumstance : they will
“ universally rank themselves on your side. We have
“ experience of this in our University, in which stu-
“ dents enjoy the fullest liberty in the choice of their
“ scientific opinions. They, in general, embrace your
“ system, and begin to use the new nomenclature.”

It cannot be said, then, that the antiphlogistic doctrine has not gained many partizans ; since it has been adopted by the greater number of the most celebrated natural philosophers and professors of chemistry in Europe ; since almost all French chemists teach it in their lectures ; and since, in opposition to twelve or fifteen chemists, in all Europe, who still refuse to admit this doctrine, there are more than fifty eminent professors, and votaries of physical science, who make it the basis of their writings and lectures. How indeed should a system of doctrine fail to strike all sound and able minds with its beauty and lustre,—which admits no hypothesis,—insists upon nothing but the results of facts,—explains most of the phenomena of nature and art, with a simplicity and a facility which were unknown before in physical science ? How should experiments so carefully performed, and so accurate, or a logic so cogent and rational, fail to persuade every unprejudiced mind ? Let the history of modern chemistry be candidly studied ; let those works be read with deep attention, and all those dissertations, which have been written within these ten years against the antiphlogistic doctrine ; and it will soon be discerned, that those chemists who still combat this doctrine, may be divided into two classes. Of these, *one* part do not understand

even the bases of this doctrine, and appear to be strangers to the train of experiments on which it is founded*. The prejudices of such men are not to be overcome, or convinced: the long-formed habit of imperfect and inaccurate processes, and the strength of old opinions, absolutely unfit them for new, general conceptions. The *other* class may be said to be under the influence of a party spirit, and are more formidable. They are acquainted with our modern experiments; they say, that they have repeated them; they have themselves made discoveries in this new chemistry: Yet,

* M. Baumé has published, at the end of the new edition of his *Elements of Pharmacy*, an appendix, expressly intended to make an open declaration against the new doctrine, to deny the composition of water, and to decry the new nomenclature. It is unlucky for him, that every line in his book shews him not to have comprehended this doctrine; to calumniate without understanding it; to have repeated none of the experiments upon which it is founded, with sufficient accuracy; and to be altogether a stranger to the spirit of modern physics. Works, whose authors thus betray their own ignorance, cannot deserve reputation. Nor have we forgotten the unlucky fate of those experiments and opinions of M. Baumé, which represented filices as convertible into argill by fusion with alkalis; or those which held forth a pretended production of boracic acid from fat and argill; or those concerning the spontaneous irreductibility of the *Persian precipitate*; the preparation of æthers, Starkey's soap, metallic salts, with excess of base, sulphuric salts with excess of acid, &c. &c.

It is more surprising that such warm objections should have been made to the pneumatic theory by M. Monnet, who performed many valuable services to chemical science, before the discovery of the gasses. Without having thoroughly studied, as it should seem, the modern doctrine; without having sufficiently acquainted himself with the new experiments and processes which it has employed; he, with great heat,

Yet, they attack the antiphlogistic theory with arms seemingly stronger than those of the former class. The only difference between them and the antiphlogistians, consists in their logic and mode of reasoning. Instead of taking the shortest and most direct way to arrive at the end proposed, they take a long, circuitous progress. What proves them not to be in the true road, is, that every one of these phlogistians forms a theory for himself in his own way, which has little or no connexion with any other theory: so that there are as many *different*

sets himself in opposition even to Scheele, to whom we owe many of those discoveries, which other chemists have since confirmed; he talks of the oxalic acid, the oxygenated muriatic acid, the arsenic acid, as if he had never seen any of these acids, as if he had never obtained them in any of his processes. He confidently pronounces, that no such acids exists; that the pneumatic chemists are all mistaken; and that their system is not tenable. Yet, on reading his dissertation against the pneumatic chemistry, which is inserted in the fourth volume of the Memoirs of the Academy of Turin, it is easy to see that he has not fully comprehended the system of the modern chemists; and, what is more inconceivable, that he has not performed any of his experiments with that accuracy, and those processes which were requisite to procure the results which he refuses to acknowledge. In a word, with his method of operating, and with that disdain which he shews for the calculation of the proportions in analyses, it was impossible that he should rightly appreciate the modern discoveries; and he denies their existence, because they have, in fact, to him no existence. We would wish persons who have studied the new chemistry, to read the dissertations here cited. They will soon be convinced of the truth of our assertions, and will perceive the reasons why, notwithstanding so much opposition; the modern doctrine daily acquires new partizans, and whence it comes to reckon among its partizans, three-fourths of all that is eminent among the philosophers of Europe.

different phlogistic theories, as there are philosophers averse to the antiphlogistic doctrine.

All the philosophers who now admit the pneumatic doctrine, beside being much more numerous than those who oppose it, have also the advantage of being at one among themselves. This ought to weigh decisively with persons engaged in the study of chemistry, if they cannot trust to their own judgement, and determine for themselves.

E L E M E N T S
OF
N A T U R A L H I S T O R Y
AND
C H E M I S T R Y.

P A R T I.

GENERAL FACTS; *and* INTRODUCTION *to the*
WORK.

C H A P. I.

*Definition of Chemistry; Chemical Processes; and the
Advantages of the Science, &c.*

CHEMISTS have not generally agreed concerning the most proper definition of chemistry. Boerhaave, in his Elements, has ranked it among the arts, or, to speak more accurately, has defined only the practical part of it. Chemistry, according to Macquer, is a science, the object of which is to discover the nature and properties of all bodies by means of analysis and synthesis. This definition is indisputably the best that

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has yet been given. But as analysis and synthesis cannot be employed with equal success in investigating the properties of all natural bodies, it would perhaps be better not to mention them at all when we attempt to define this science. The chemist cannot attain the knowledge of the properties of bodies without bringing them into contact; and as all that he can possibly discover is only the mutual operations of bodies; perhaps the following definition may deserve to be adopted, even in preference to Macquer's: **CHEMISTRY IS THAT SCIENCE WHICH EXPLAINS THE INTIMATE MUTUAL ACTION OF ALL NATURAL BODIES.** The facts which we are to relate will illustrate this definition. In order to display the extent of this science in an orderly and perspicuous manner, we shall consider the subjects upon which it is engaged; the means which it employs; the purposes it pursues; and the advantages which it affords.

§ I. Concerning the Object, the Methods, and the Intentions, of Chemistry.

THE *subjects* on which the labours of the chemist are engaged, are all the substances that compose the globe which we inhabit, whether buried in its interior parts or found at its surface. Chemistry is therefore of equal extent with natural history, and the same limits are common to both.

Analysis or decomposition, and *synthesis* or combination, are the two *processes* which chemistry employs to accomplish its purposes. The first is nothing but the *separation* of the constituent parts of a compound substance.

stance. Cinnabar, for instance, is a composition of mercury and sulphur; the chemical art analyses it by separating these two bodies from one another. Till of late it was generally thought, and many are still of opinion, that this method is more advantageous in chemical researches than the other. This opinion had even gained such ground among the learned as to induce several of them to define chemistry, *The science of analysis*. But nothing can be more inconsistent with the just idea of decomposition. In order to set this important truth in a proper light, we must divide analysis into two kinds; the true or simple, and the false or complex. The *true analysis* is that by which the component principles of the body decomposed, are obtained, without suffering any alteration. The only criterion by which we can distinguish whether this analysis has taken place, is when, by reuniting the simple substances to which the compound body has been reduced, we can form a new compound precisely similar to the former. Cinnabar will again furnish an instance. When the two substances of which this composition is formed, namely mercury and sulphur, are separated by a chemical process, they are found to be in a state of purity similar to that which they possessed before their separation; for by uniting them we can form a new body, differing in no respect from the original cinnabar. But unfortunately for the science, this kind of analysis can seldom be effected. Chemists are not so happy as to be able to apply it to many of the bodies on which they make experiments. The neutral salts, and a few other mineral substances, are the only bodies in nature susceptible of this species of decomposition.

The *false or complex analysis* is that by means of which a body is resolved into principles different from those which appeared to exist in the composition, and incapable of forming, by their reunion, a body similar to that from which they were obtained.

This kind of decomposition takes place in most of the bodies that are subject to a chemical analysis; no other condition being requisite, but that more than two principles enter into the combination to be examined, and that they be united by a certain degree of mutual affinity. Many minerals, and all vegetable and animal substances without exception, admit of no other species of analysis. Thus sugar, distilled in a retort, affords an acid, an oil, and a carbonaceous residue; but all attempts to recombine these into the same substance from which they were obtained, are uniformly fruitless. This kind of analysis cannot enable us to discover in what state substances existed together in any combination before being separated; and it therefore affords but little useful information, and is not to be trusted without the greatest caution. By trusting too hastily to results of this kind, chemists have afforded room for all that censure to which their art has been exposed. On this account has chemistry been accused of absolutely destroying bodies in its attempts to separate their component parts; and we cannot but acknowledge that the censure was for a long time just: but becoming more circumspect in proportion to her progress, chemistry now rejects that deceitful analysis to which she formerly had recourse, and possesses the means of examining the properties and distinguishing the component principles of bodies

dies, without destroying their nature. She even proceeds farther, and, as we shall have occasion to mention more particularly when we come to treat of vegetable substances, estimates the mutual action of principles, and determines by what causes they are thus modified and changed.

Synthesis or composition, the second method of prosecuting chemical inquiries, is the formation of a compound by the artificial reunion of several principles. Its utility, its extent, and the dependance that may be placed on the results which it affords, render it much more valuable than the other: nay, not even a single operation in chemistry can be conducted without producing some new combination. Chemists appear not to have been sufficiently sensible of its importance. In fact, as synthesis is both more frequently employed and more highly useful than analysis, chemistry might be, with a good deal of propriety, represented as the science of combination, not of analysis.

These two methods are sometimes employed separately, but oftener together. It frequently happens that a true analysis cannot be effected without the help of some combination. False analyses are always accompanied with new combinations by synthesis; nay, composition itself often produces a kind of analysis. The last of these facts, however, has been but lately discovered. The discovery of a great number of aeriform fluids, the existence of which was not formerly so much as suspected, has shown that in many operations which were considered as simple combinations, an invisible elastic fluid is disengaged with effervescence, and

either escapes into the atmosphere, or is received in vessels which have been ingeniously contrived to confine it. Most of the combinations of two principles which were before thought to be simple substances, exhibit this kind of analysis. We shall have occasion to give frequent instances of it, when we come to treat of neutral salts.

From this short account of the analysis and synthesis of the chemists, it appears that the whole art of chemistry consists in promoting the intimate mutual action of bodies, and in observing carefully the phenomena with which it is attended. It is to be remembered that Nature herself constantly employs these two methods, and that from her the chemist first learned to use them. As they depend on the mutual affinities of bodies, all that the artist can do is to dispose these in such a manner that they may act upon each other. The young chemist ought carefully to acquaint himself with these important truths: for these, with the rest to be explained in the following chapters of this first part, form the basis of the science.

Hence it is very easy to comprehend the final intention of chemistry. That cannot be merely to discover the first principles of bodies; for there are many substances which cannot be resolved into others more simple, and whose component principles are therefore unknown: yet these substances, though not susceptible of analysis, admit of combination, and act upon other bodies; and therefore it appears evident, that the chief design of chemistry is to discover the mutual actions of natural bodies, to distinguish the order of their combinations

nations, and to estimate the strength of that mutual attraction which gives them a tendency to unite and to remain in union.

§ II. Concerning the useful Purposes to which Chemistry may be applied.

A PARTICULAR treatise would be necessary to give a full view of all the advantages which mankind derive from this science. As the design of this work does not admit of our entering minutely into that subject, we shall content ourselves with exhibiting its outlines; insisting, however, more particularly on such of them as appear not to have been hitherto considered with all the attention which they deserve.

Chemistry is beneficial to so many of the arts, that we may arrange them all under two divisions: the first, comprehending all the mechanical arts which depend on the principles of geometry; the second, including all those which depend upon chemistry, and therefore merit the name of chemical arts. These last are much more numerous than the other. As they are all founded on chemical phenomena, it is easy to see that the practice of them ought to be regulated by the rules of chemistry; which, by new discoveries, simplifies the processes, renders their success more certain, and even extends the limits of all the arts dependant upon it. These are, *1st*, The arts of making bricks, tiles, china, porcelain, and the other species of earthen ware; all of which are preparations of different kinds of clay, baked into different forms, and exposed to the action of heat

till each may have acquired its proper degree of hardness. *2dly*, The art of making glass; which, by combining a vitrifiable earth with a saline substance, produces a new body, hard, transparent, and almost impregnable by the action of the air: A wonderful art, from which mankind have derived many important advantages! *3dly*, The arts of extracting metals from their ores, of casting, of purifying, and of alloying them by mixture, owe also their origin and progress to chemistry, which is daily throwing new light upon them. *4thly*, The vegetable kingdom affords materials to a great number of arts, which, as well as those above-mentioned, belong to the province of chemistry. The arts of converting saccharine juices, or farinaceous substances, into vinous liquors; of extracting from these liquors the ardent spirit which they contain; of separating that spirit from the water with which it is at first combined; of uniting this ardent spirit with the aromatic parts of plants; of extracting the colouring matter of plants, and applying it so as to tinge stuffs; and, lastly, the arts of converting wine into vinegar, and combining vinegar with various substances; of separating from grain and other parts of vegetables that precious substance of which we form bread; and of converting so dry and insipid a body as meal, into a light, digestible, and pleasant substance; all these arts, and many more, which our present limits allow us not to take particular notice of, belong to the province of chemistry, and are indebted to this science for their present perfection, and in many instances for their first invention *.

It

* *The art of bleaching is wholly chemical.*—H.

It has equal claims to the honour of being the mistress or parent of all those arts which are employed on animal substances. Such is the useful art of cookery ; the true end of which is not to flatter the palate, or to vary the forms and flavours of meats, for the gratification of capricious taste ; but to render aliments easy of digestion, by means of boiling, or by applying to them mild and natural seasoning. Hat-making, and the dressing, tanning, and currying of leather, belong to the same class of arts. But one of the most valuable of all the arts, which indeed occupies a middle rank between the arts properly so called, and the sciences, and to which chemistry is singularly useful, is pharmacy. Every person concerned in pharmacy needs a very extensive knowledge of chemistry, that he may not be ignorant of those alterations to which the bodies he makes use of are subject ; may know how to prevent or correct such alterations ; may be enabled to discover the changes which compound medicines undergo ; and, in a word, may foresee readily the combinations or analyses that may be produced by the mixture of any simple drugs. Every impartial person must agree, that to acquire a competent skill in pharmacy, the student ought, after acquainting himself with the natural history of the *materia medica*, to turn his attention to chemistry, and study it with the most earnest assiduity. By these means only, can pharmacy be practised on certain principles, so as to render to mankind those important services which entitle it to the high rank it holds among the arts *.

A

* It is probable that *agriculture* may be greatly benefited by the application

A very cursory view of the sciences will be sufficient to convince us of what important benefits they derive from chemistry. To natural history it is peculiarly beneficial. The earlier naturalists employed physical properties of colour, form, consistency, the distinguishing characteristics of minerals: but these properties being very liable to variation, the benefits which ancient philosophers have spoken of are not known, and their discoveries are almost total. The moderns have become sensible, that, in order to obviate this inconvenience so fatal to the progress of natural history, some new method must be adopted. Chemical analysis has been thought the happiest that can be employed; and by this method such progress has already been made, that minerals are now arranged in classes according to the nature and quantities of the principles of which they are composed. The progress made in this branch of natural history is owing to the labours of Messrs Bergman, Bayen, Monnet, Wallerius, Cronstedt, and some other naturalists who began the arrangement of mineral bodies according to their chemical properties. M. Bucquet, in his courses of lectures, had improved on the ideas of these two celebrated naturalists; and his mode of arrangement was entirely chemical. M. Sage, who has analysed a great number of minerals, has also employed the same chemical mode of arrangement: and though no

application of chemistry to discover the operation of *manures*, the principle of fertility in soils. *Lord Dundonald's* late work, *Kirwan's essay* in the *Transactions of the Royal Irish Academy*; and *other attempts* in this way.—H.

has adopted the whole of his theory, yet mineralogy owes to him the highest obligations; and few in France have pursued the study with greater industry and success. M. Daubenton has availed himself of the labours of all his contemporaries and predecessors; examining them, however, with a degree of caution worthy of the true philosopher, whose proper object is to discover truth amid that maze of error and uncertainty, in which, unfortunately for mankind, it is too often concealed. Nothing, then, can be more certain than the utility of chemistry to natural history; it affords the only means of removing that obscurity and uncertainty which must ever attend simple descriptions of natural objects. One observation of M. Daubenton merits the particular attention of all chemical philosophers: He advises them to describe carefully the specimens on which they make their experiments, in order that they may be generally understood by naturalists, and may avoid that confusion which, according to this celebrated professor, prevails through the works of many modern chemists. The only means which I have found proper for avoiding that confusion, is, to connect the two sciences in my lectures, by uniting physical descriptions of bodies with an account of their chemical properties.

But the world are not so generally convinced of the usefulness of chemistry in medicine. The errors of the chemical physicians of the last century, and the indifference of a number of medical practitioners for this science, have impressed many with an unfavourable opinion of it, which time alone can remove. Yet, it would surely be better not to lend an ear to the voice of prejudice,

prejudice, but to inquire candidly into the causes of those mistakes which chemists have committed, and to consider by what means they may be for the future avoided, and the science restored to its just honour. Though the first physicians who cultivated chemistry were misled by a blind enthusiasm; yet from that many inferences can be drawn applicable to the chemistry of the present time. The precision which the moderns have introduced into every part of experimental philosophy, cannot but remove all the apprehensions which might be entertained, if chemistry were still involved in the same degree of mystery and obscurity in which it was a century ago. If employed with caution, and with a due regard to the extent of its powers, it cannot but be highly beneficial to medicine. After thus acknowledging the whims and blunders of chemists, let us proceed to justify the science, by examining how far it is useful to every branch of medicine. Let us first distinguish between the two great departments of this extensive science, namely, the theory and the practice; which, however, ought not to be entirely separated from each other, as they have been by some authors. The study of medicine ought always to begin with the anatomy of man and the other animals. But the solids are the only part of the animal frame subject to the examination of anatomy; while it is well known to physiologists, that the greatest part of animal bodies consists of fluids, by the motion of which life is maintained. Were we then to confine our observation to the structure of the vessels, without examining the nature and properties of the fluids which they contain, we should be

acquainted

acquainted with only one part of the animal system. It is the business of chemistry to explain to us the qualities of these fluids : chemistry affords the only means by which we can acquire a knowledge of the principles of which they are composed, and of the changes which they undergo in performing those functions by which they contribute to the support of life. Without the aid of this science, it would be impossible for us to discover the mechanism of the animal functions ; to distinguish between the various fluids separated by the different viscera ; to observe what alterations these suffer when collected in their several reservoirs ; or to understand how they are affected by heat, cold, or mixture with other fluids, &c. When we are thus far acquainted with the composition of animal fluids, it will next be proper to examine what variations they are liable to, from differences of sex, age, constitution, climate, and season ; and to trace them through the various species of animals. Thus shall we establish certain points of comparison, by means of which the limits of science may be extended. It is not enough, however, to examine the chemical properties of the animal fluids when the system is in a sound state : they should be observed with no less attention when the body languishes under disease, in order that it may be certainly discovered what alterations they suffer in the various distempers to which the human frame is liable ; what part of the humours predominates in putrid, inflammatory, scorbutic, or scrophulous disorders ; what saline combinations are formed during the progress of the distemper ; what matter extruded from its proper vessels. Such researches cannot

fail to make physicians better acquainted with the history of pathology. We think it equally necessary to examine the solids by chemical methods, in the sound as well as in the diseased state of the body; that by considering their properties, we may discover from what fluid they are produced; and, this known, may conjecture upon good grounds, what solid or fluid has suffered alteration in any distemper. This position, which is here but slightly mentioned, will be more particularly explained in the chapters on Animal Matters.

But chemistry is no less useful to the practice than to the theory of medicine; nor can it indeed be useful to the one without promoting the other at the same time. It will, therefore, be no difficult task to show the dependence of the practice upon the science. To begin with the art of preserving health; an accurate chemical knowledge of the various articles of food, and of the atmospheric fluid, is necessary to enable us to make a proper choice of air and aliments. By chemistry we learn what quantity of nutritive matter is contained in every different article of food; in what particular state that matter exists in each of the bodies in which it is found; the nature of the several substances with which it may be combined; and the means of extracting, purifying, and preparing it in a manner suitable to the strength or weakness of different stomachs. It is the same science that explains to us the nature of those fluids which we use to drink; what properties render water wholesome or noxious, and how to separate from it whatever may render it injurious to the animal economy; what are the principles of fermented liquors,
and

and in what proportion those are mingled together in the several kinds of wine ; as also by what processes we may distinguish whether wine be genuine or adulterated. Lastly, by the same means we learn, what properties render air fit for respiration ; to what changes this fluid is liable ; and what other substances are capable of altering its purity, by entering into combination with it. Chemistry likewise supplies us with the happy means of correcting the qualities of air when noxious, so as to restore it to that state in which it is proper for respiration : for the discovery of which means we are indebted to the industry of the moderns, as will be shown in the History of Air *.

The physician ought not to make use of medicines unless he know their nature ; and this knowledge he must learn from chemistry. This has been so long generally acknowledged, that the writers of the *materia medica* arrange medicines by their chemical properties. The uniform experience of all ages has established it as a certain truth, that there is a close and natural relation between the taste of bodies and the manner in which they act on the animal œconomy ; so that by tasting any substance we may judge of its medicinal qualities : Bitters are stomachic ; insipid substances, mild and relaxing ; bodies of an agreeable sweet taste, nutritious ;
acid

* The application of aërisform fluids to the cure, particularly of *consumption* and *cancer* ; which has been attempted in Britain. by *Drs. Beddoes, Ewart, Darwin*, and others ; if finally successful in such a number of unequivocal cases, as may recommend it to the practice of physicians in general ; will greatly enlarge the range of the utility of chemistry in medicine.—H.

acid substances, active, penetrating, and incisive. But as taste is undeniably a chemical property, depending on the tendency of substances to combination, as shall be elsewhere shown, we must confess ourselves indebted to chemistry for whatever knowledge of the properties of bodies we can gain by examining their taste. Yet would be absurd to suppose, with the chemical physicians of the last century, that the stomach is a vessel in which chemical processes are carried on, as in a laboratory. The intestines possess indeed sensibility and a peculiar motion, which modify the nature and operation of such medicines as are administered; but it becomes the physician to repress those wild fallies of imagination which lead to ridiculous hypotheses, and to admit only such facts as are established by accurate observation. It cannot be denied, that, in some cases, medicines act in the first passages by means of their chemical properties; then, indeed, the physician may apply his chemical knowledge. Long experience has shown, that in the diseases peculiar to children, the stomach and intestines are coated with a tenacious viscid matter, which is manifestly of an acid nature. The absorbent earths, and alkalis administered on such occasions, destroy this acid by entering into combination with it, and form a neutral purgative salt, which by stimulating the intestines, causes them to evacuate the noxious matter. All diseases that occasion an accumulation of obstructive matter in the primary passages, require the physician to possess some chemical knowledge; as it is certain that some substances will act with more force than others on that obstructive matter. Thus, for instance, acids may
be

be administered to remove one kind of obstruction, and a solution of salts for another.

But the greatest advantage which the practitioner of medicine can derive from chemistry, is on those alarming occasions when, by accident or design, some of those corrosive substances have been swallowed, which prove fatal to life by attacking the viscera, and destroying their organization. On such occasions chemistry lends the readiest and most effectual aid to medicine, by supplying substances which have power to decompose the poison, and by that means obviate its direful effects. Navier, a celebrated medical chemist of Chalons, has published a work, in which he points out effectual remedies to prevent the destructive effects of the poisons of arsenic, corrosive sublimate, verdegris, or the preparations of lead. Notwithstanding the angry declamations of some physicians, who seem desirous of excluding the sciences from the practice of medicine, his work well deserves the gratitude of posterity. Not only does chemistry at present enable us to counteract effectually the operation of mineral poisons; but there is even reason to hope, that careful inquiries into the nature of animal and vegetable poisons, may enable us to discover some substances capable of divesting them also of their pernicious powers. Opium, and all narcotic vegetables, the acid and caustic juices, such as those of spurge and euphorbium, the noxious plants, particularly mushrooms, are all well worthy of the particular attention of the chemist; as by his researches some means may possibly be discovered which may render them hereafter less dangerous. It is of no less importance to examine the nature of animal poisons. From

the experiments of Margraaf and Fontana we are already acquainted with the acid of ants : Thouver has discovered several acrid substances in cantharide Mead has examined the venom of the viper : Fontana has pursued a train of investigation concerning the far poison ; and has discovered, that *lapis causticus*, introduced immediately into the wound made by this reptile, decomposes the poison, and prevents its effects.

Did chemistry even contribute less in these instances to the benefit of medicine ; yet still by supplying such a number of valuable drugs, she must be confessed to render services of the highest importance to this useful science. *Stibiated* tartar, together with the various mercurial, antimonial, and martial preparations, which are so often and so successfully prescribed, when considered as the gifts of chemistry, must surely induce physicians to esteem the science, and to encourage those who prosecute chemical researches from a desire to contribute to the advancement of medicine. As for myself, the natural bent of my genius, no less than my particular situation, leads me to cultivate both these sciences with the most earnest wishes to promote their improvement. The declamations of those, who from their ignorance of chemistry, are induced to represent it as of no utility in medicine, shall never detach me from its pursuits. I have engaged with ardour in the study of animal chemistry, and am determined to follow the steps of those who have already prosecuted with so much success.

To conclude our observations on the utility of chemistry to medicine ; we shall only add, that a certain degree of chemical knowledge is absolutely necessary to enable

enable the physician to make out a prescription of any compound medicine, to be prepared by the apothecary. Persons unskilled in chemistry are liable to commit the grossest blunders daily in making out prescriptions ; to order, for instance, the composition of substances incapable of subsisting in union, or which have a mutual tendency to decompose one another. In the case of decomposition, the medicine administered cannot possibly produce the desired effects. Chemistry furnishes the only means to prevent such blunders ; which are often attended with the most unhappy consequences. If possessed of chemical knowledge, we will never attempt to compound together substances incapable of mutual combination ; the laws of chemistry must always direct us in the preparation of compound medicines. Without a knowledge of chemistry, the physician must ever be liable to commit numerous blunders ; which, though they should be followed by no other bad consequences, cannot but expose him to the contempt of the apothecary ; as the practice of the apothecary naturally makes *him* acquainted with many chemical facts.

The usefulness of chemistry in the arts, and the resemblance of its processes to the manipulations of artists, have caused it to be confounded sometimes with alchemy, sometimes with pharmacy ; though *they* must be very ignorant indeed, who can thus confound objects so widely different from one another, and can regard the chemist as a fanciful projector, unweariedly employed in a vain search for the philosopher's stone. Even a very slight attention to the nature and pursuits of chemistry, may be sufficient to convince any person

that there is a vast difference between those purpose which the chemist pursues in a train of regular connected researches, and the transmutations which the alchemist pretends to effect by a set of absurd and desultory processes. That mistake which leads many people to regard chemistry as the art of preparing drugs is more excusable ; it confounds not the chemist with the ignorant and insignificant operators of the Great Work, who, as is humorously observed by Macquer, are the artisans of an art which has no existence ; but associates him with a class of useful and respectable artists, whose labours are of high importance to society. Yet as pharmacy is but one branch of chemistry, to confine chemistry to the making up of medicines, is to entertain a very unjust idea of the extent of the science. Pharmacy, as well as all the other arts dependant on chemistry, is guided and assisted in its operations by this science. But chemistry, in its nature and objects, is more sublime and extensive ; it extends its inquiries and inductions to the reciprocal action of all the bodies in nature ; and thus contributes at the same time to the advancement of both philosophy and the arts.

C H A P. II.

The History of Chemistry.

E student of any science should make himself acquainted at least with the outlines of its history. A knowledge of the leading facts, and of the dates of discoveries, will be of use to enable him to avoid errors of those who have preceded him in the same science, and to direct him to the path which leads to improvement. But as a very minute detail of the history of chemistry might possibly be considered as an unnecessary digression from the main object of this treatise, we shall confine ourselves to a view of leading facts, without entering into particulars. Whoever is desirous of more information concerning the rise and progress of chemistry, may consult a variety of well-written works which have been published on the subject; particularly, the Treatise of Olaus Borrichius, *de ortu et progressu Chymiae*; the article *Chimie* in the *Dictionnaire encyclopédique*; the Introduction to Senac's Treatise on the Human Mind; Abbé Lenglet du Fresnoy's History of the Human Philosophy; the first Chapter of Boerhaave's Abridgement of the Art of Medicine; the Discourse prefixed to Macquer's Chemical Dictionary; Bergman's Essay on the History of Chemistry, &c.

In order to give the reader a brief and methodical account of the progress of the human mind in the study of chemistry, and of the successive discoveries which have been made in this science; we shall divide our history into six

I.

The origin of Chemistry among the Egyptians, and its progress among the Greeks.

THE origin of chemistry is hid in the same obscurity which conceals that of the other arts and sciences. The patriarch Tubal-Cain, who lived before the flood, considered as the inventor of chemistry; but the only part of it known to him was the art of working metals; he seems to have been the same with the Vulcan of fabulous history.

We may with more confidence ascribe the invention of this science to the ancient Egyptians. According to Abbé Lenglet du Fresnoy, Thoth or Athotis, surnamed Hermes or Mercury, is the first of this nation of whom mention is made as being a chemist. He was the son of Mezraim or Osiris, and the grandson of Cham. He became king of Thebes.

Siphoas was the next Egyptian monarch, who was also distinguished as a philosopher. He lived 800 years after Athotis, and 1900 before Jesus Christ. He is named Hermes, or Mercury Trismegistus, by the Greeks and is therefore the second Mercury: he is considered as the inventor of natural philosophy; he wrote two and forty books on the subject of philosophy, the titles of which have been handed down to us by various historians. None of them seems to have treated directly of chemistry; though from him has the science been intitled the Hermetic Philosophy.

We know but little concerning those who cultivated chemistry among the Egyptians; but the science a

pears to have made considerable progress among them, for they practised many of the arts dependant on chemistry; particularly the arts of forming imitations of the precious stones, of casting and working metals, of painting upon glass, &c.: but the chemistry of this ancient people has been lost, as well as their other arts and sciences. The priests involved them in mystery, and concealed them under the veil of hieroglyphics. Alchemists have persuaded themselves, that some vestiges of their pretended art may be traced among the remains of the Egyptian hieroglyphics; and that the temple which the Egyptians dedicated to Vulcan was erected in honour of alchemy.

The Israelites acquired a knowledge of chemistry from the Egyptians. Moses is considered as a chemist, on account of his dissolving the golden idol which the people had set up. It has been thought, and Stahl has even written a dissertation to prove, that he rendered the gold soluble in water by means of liver of sulphur. Such a process supposes a pretty extensive knowledge of chemistry.

Democritus of Abdera, who lived about 500 years before Jesus Christ, travelled into Egypt, Chaldea, and Persia, &c. and is said to have gained some skill in chemistry in the first of these countries. Though the son of a man whose opulence had enabled him to entertain Xerxes and all his attendants, he returned very poor to his native country, where he was kindly received, however, by his brother Damassus. Retiring to a garden near the walls of the city of Abdera, he employed himself in the study of plants and precious stones. Cicero asserts, that Democritus, in order that he might

not be diverted from his speculations by external objects, deprived himself of sight by gazing on the rays of the sun reflected from a vessel of polished copper: But Plutarch denies this fact. Pliny was so amazed at the knowledge of Democritus, that he considered it as quite miraculous.

Some authors reckon Cleopatra a chemist, because she knew how to dissolve pearls. It is even affirmed, that the art of chemistry being known to all the Egyptian priests, continued to be practised among that nation till the time when, according to Suidas, Dioclesian thought to reduce them more easily under subjection, by burning their books on chemistry.

II.

The Chemistry of the Arabians.

AFTER a long series of ages, through which it is impossible to trace the progress of chemistry amid the revolutions of empire; this science again appears among the Arabians, and cultivated so successfully as to merit our attention.

Under the dynasty of the Achemides, or Abassides, the sciences, which had long been neglected, regained their former vigour. Almanzor, the second Caliph of this family, eagerly cultivated astronomy. Harun Raschid, the fifth Caliph, who was cotemporary with Charlemagne, caused several books on chemistry to be translated from the Greek into the Arabic.

In the ninth century, Gebber of Thus, in Chorazan, a province of Persia, wrote three different treatises on chemistry; which contain a number of tolerably good things.

things. His masterpiece is entitled, *Summa perfectionis magisterii*. He has written with considerable perspicuity on distillation, calcination, the reduction and the solution of metals.

In the tenth century, Rhazes, physician to the hospital of Bagdad, first applied chemistry to medicine. Some of his pharmaceutic prescriptions are still in esteem.

In the eleventh century, Avicenna, a physician, in imitation of Rhazes, applied chemistry to medicine. His merit raised him to the office of Grand-Vizir; but his debaucheries occasioned his degradation from that office.

III.

Chemistry passes from the East to the West, in the time of the Crusades : Reign of Alchemy.

THE art of making gold continued long in repute, according to the authors who have written upon it. But the madness that gave rise to it was at its greatest height between the eleventh and the sixteenth century. The chemical facts which had been discovered by the Egyptians, collected by the Greeks, and applied to medicine by the Arabians, became known to the four nations who visited the east in the Crusades; and England, France, Germany, and Italy, soon swarmed with a set of men eager in search of the philosopher's stone. As their labours contributed to the advancement of chemistry, it is but reasonable to take notice of some of the most distinguished among those singular geniuses.

In the thirteenth century, Albert the Great, a Dominican of Cologne, and afterwards of Ratisbon, was repu-

ted a magician ; and composed a work, which contains descriptions of many alchemical processes.

Roger Bacon, born in the year 1214, near Ilchester in the county of Somerset, studied at Oxford, and came afterwards to Paris to prosecute his studies in mathematics and medicine. He is celebrated as the author of several inventions ; any one of which might well entitle him to immortality. Among these are the camera obscura, the telescope, and gunpowder. He is said to have made a self-moving chariot, a flying machine, a speaking head, &c. He was a cordelier, and was surnamed the *Admirable Doctor*. Being accused of magic, his fellow monks were obliged to imprison him. He afterwards resided in an house in Oxford, where he is said to have worked in alchemy. Borrichius saw the house, which was still known by his name *.

Arnold of Villeneuve, born in Languedoc in 1245, died in 1310, having studied medicine at Paris for 3 years. He wrote a commentary on the Schola Salernitana. The alchemists respect him as one of their greatest masters. Borrichius, in the year 1664, saw one of his descendants, an alchemist, in Languedoc.

Fourteenth century. Raymond Lully, born in Majorca in 1235, came to Paris in 1281; where he became acquainted with Arnold of Villeneuve, and studied under him. Robert Constantine relates that he had seen in the Tower of London, a Rose Noble struck out of gold, made by Lully, under the reign of Edward V. in the

* Concerning this house, if I mistake not, a tradition has been long known at Oxford ; that when a greater man than Roger Bacon passed beneath it, it will tumble down upon his head. It stands on a bridge

“ And Bacon’s mansion trembles o’er his head.” JOHNSON.—I

the years 1312 and 1313. He has left several books on alchemy, which contain some facts relative to the preparation of acids, or aquafortis, and the properties of metals.

Fifteenth century. Basilius Valentinus, a Benedictine of Erfort in Germany, was skilled in medicine and natural history. He has left a work on antimony, under the pompous title of *Currus triumphalis Antimonii*, on which a commentary has been written by Kerkringius. This book describes a considerable number of antimonial preparations, which have been since offered to the world as new discoveries, under different names, and have been prescribed with great success for the cure of several disorders.

The two Isaacs of Holland, father and son, though but little known, have left some treatises which are praised by Boerhaave, and from which they appear to have been acquainted with aqua fortis and aqua regia.

All these authors have written on chemistry in a very obscure confused manner. Though acquainted with some processes of solution, extraction, and purification, &c. their pretensions rose much higher than their knowledge; and scarce any advantage can be derived from a perusal of their works.

IV.

The universal Medicine ; Pharmaceutic Chemistry ; Alchemy opposed, from the sixteenth to the middle of the seventeenth Century.

THOUGH the vain projects of the alchemists had been invariably unsuccessful, and had been almost always attended with the loss of fortune and reputation ; yet, in
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the sixteenth century, a prodigious number appeared at the head of whom was Paracelsus, a Swiss physician born at Zurich in 1493, whose reveries were eagerly embraced by the rest. This fanciful man asserted, that there was an universal medicine, and substituted chemical preparations in the place of the Galenical pharmacy then in use. He cured many diseases in which the ordinary remedies had been ineffectually applied, and particularly venereal complaints with mercurial preparations. He performed some very surprising cures; but became so extravagantly flushed with his success, as to burn in public the writings of the Greek physicians. He died amid his imaginary triumphs in an inn in Saltzburgh, at the age of 48, after having promised himself immortality from the use of his secrets.

Notwithstanding the extravagance and absurdity of his idea of an universal medicine, it attracted the attention of alchemists, and revived the spirit of alchemy. Several imagining that they had discovered the universal medicine, assumed the new title of *Adepts*. Among these were, at the beginning of the seventeenth century.

1. The Rosicrucians, a fraternity that arose in Germany, were never known but by name in France, and whose individual members never made any public acknowledgement of their principles: They pretended to be in possession of the art of transmutation, the universal science, the universal medicine, and the science of occult things, &c:

2. A wandering fellow, named Alexander Sethon or Sidon, who is said to have performed the work of transmutation in Holland, in the presence of a person of the name of Haussen: Haussen related the fact to

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Vander Linden, grandfather to the physician of that name, who collected a medical library :

3. Another named Thomas Vaughan, born in England in 1612. He went to America, where Starkey saw and received gold from him. Boyle corresponded with him. This is the same adept who, in France, gave his powder of projection to Helvetius. The latter, in consequence of this pretended miracle, which was nothing but a trick, wrote a dissertation *De Vitulo aureo*, &c.

Yet the success with which Paracelsus had prescribed his chemical medicines, induced a number of physicians to cultivate that new art ; and in a short time several valuable works appeared on the preparation of chemical medicines. Such are the works of Crollius, Schroder, Zwelfer, Glafer, Tackenius, Lemery, &c.; as well as the pharmacopœiæ published by the principal faculties of medicine in Europe. About this time Glauber, a German chemist, rendered an important service to his art, by examining the residues of operations, which had hitherto been always thrown aside as useless, and distinguished by the name of *caput mortuum*, or *terra damnata*. He discovered by this means the neutral salt which bears his name, and the ammoniacal vitriolic salt, and explained the chemical processes necessary in preparing mineral acids, &c.

Several of those who have contributed to the advancement of chemistry since the days of Paracelsus, were not fully convinced of the absurdity of his wild notions. Among these were Cassius, known for his precipitate of gold ; Sir Kenelm Digby, who believed in the sympathetic action of medicines ; Libavius, who has communicated his name to a preparation of tin ;

Van Helmont famous for his singular notions both in chemistry and medicine; and, lastly, Borrichius, a Danish physician and chemist, who first discovered and made known to the world the possibility and the manner of inflaming oils with the nitrous acid, and who deserves the gratitude and respect of the world for having bequeathed his library and chemical laboratory to the use of indigent students of medicine.

Alchemy was now opposed by two celebrated geniuses, who were successful in their attacks. The one, the celebrated Father Kircher the Jesuit, to whom we are indebted for a noble work, intitled *Mundus Subterraneus*; the other, the learned Conringius.

V.

Rise and Progress of philosophical Chemistry, from the middle of the seventeenth to the middle of the eighteenth Century.

HITHERTO chemistry had never been treated in a philosophical manner. The chemical arts had indeed been described, medical formulæ had been given, and the nature of metals painfully examined, in the hopes of making gold, or discovering an universal medicine: A chimera still fondly believed by the ignorant and enthusiastic! But nothing more had been done. A great number of chemical facts were known; but none had attempted to form them into a system: And, as the celebrated Macquer has ingeniously observed, though many branches of chemistry were known and practised, the science itself was not yet in existence.

Towards the middle of the seventeenth century,
James

James Barner, physician to the King of Poland, arranged the principal facts then known, in a methodical manner, accompanying them with observations, in his *Philosophy of Chemistry*. The work of that learned author is the more valuable, on account of his being the first who attempted to form a complete system of chemical knowledge, and ranked chemistry among the sciences.

Bohnius, professor at Leipzig, wrote also a book on scientific chemistry, which was very favourably received by the world, and was long the only elementary book on the subject.

Joachim Beccher of Spire, a man of very considerable genius, physician to the Electors of Mentz and Bavaria, distinguished himself so highly in this science as to cause the names of the two last mentioned writers to be almost entirely forgotten. In his noble work, intitled *Physica subterranea*, he has collected all the chemical phenomena at that time known, and has described them with amazing accuracy. He has even foretold many of the discoveries which have been successively made since he wrote; such as the existence of aeriform or gaseous substances; the possibility of reducing animal bones into a transparent glass, &c. A celebrated physician, whose name marks the commencement of a new and more illustrious æra in the annals of chemistry, has done him the honour of writing a commentary on his work. J. Ernest Stahl, who was born with a natural fondness for chemistry, undertook to illustrate the doctrine of Beccher by a commentary. His favourite object, to which he more particularly directed his attention, was to demonstrate the existence of that inflammable earth which he denominated

nated Phlogiston. Not inferior to Beccher in genius, he excelled him in accuracy and method. His treatises on sulphur and salts, together with that which is intitled *Trecenta Experimenta*, have acquired him immortal honour, and have ranked him among the first characters of the age in which he appeared.

Boerhaave, amid his various engagements, found leisure to cultivate chemistry, and composed a very profound work on this science, which has long been highly celebrated. The treatises on the four elements, particularly that on fire, which form a part of this work, are each of them masterpieces, containing all that was at that time known on their particular subjects. He was also the first who attempted to analyse vegetables; and to him we owe the spiritus rector, &c.

Stahl's theory has been generally adopted by succeeding chemists, and has acquired greater stability from the labours of the two illustrious brothers Messrs Rouelle, to whom we are chiefly indebted for the progress which chemistry has made in France, and whose loss is severely felt by the chemical world.

The illustrious Macquer, of whom death has now deprived the philosophical world, contributed in a very signal manner to the advancement of the science; and his valuable works are still justly esteemed, over all Europe, as the best guides to chemical knowledge. Beside the important services which he performed to the world, by publishing his Dictionary and Elements of Chemistry, his inquiries and discoveries concerning the nature of arsenic, Prussian blue, the dyeing of silks, clays for pottery, &c. might well immortalize his name, and intitle him to the gratitude of posterity.

VI.

Pneumatic Chemistry: the present Time.

STALE, being wholly engaged in demonstrating the existence of phlogiston, and tracing it through all its combinations with other bodies, seems to have overlooked the influence of air in most of those phenomena in which he ascribes so much to the energy of the inflammable principle. Boyle and Hales had already shown the necessity of referring many chemical phenomena to the operation of that fluid. Boyle had taken notice of the difference of the appearances which the same chemical events exhibit in the open air and *in vacuo*. Hales had obtained from a variety of bodies a fluid which he took for air, but in which he observed a number of peculiar properties; such as smell, inflammability, &c. according to the nature of the substances from which it was obtained. He was led to consider air as the principle on which the consistency and solidity of bodies depended.

Dr Priestley, by repeating a great part of Hales's experiments, discovered a number of fluids, which, though they have the appearance of air, yet differ from it in all their essential properties: and, in particular, from metallic calces he extracted a species much purer than atmospheric air.

M. Bayen, a chemist deservedly celebrated for the accuracy of his researches, examined the calces of mercury, and found that they are reducible without phlogiston, and that during the process they emit an æri-form fluid in great abundance.

M. Lavoisier, soon after this, discovered, and proved by a number of fine experiments, that in the process of burning or calcination, a portion of the air always enters into combination with the body which is calcined or burnt. In consequence of this discovery, he formed a sect of chemists who agreed with him in doubting the existence of *phlogiston*, and ascribed to the fixation or the disengagement of air all those phenomena which Stahl had referred to the separation or the combination of *phlogiston*. It must be granted, that this doctrine has been more fully demonstrated than Stahl's; and that it agrees better with that accuracy and method which have of late been introduced into the study of natural philosophy. In this light did it appear to the late M. Bucquet, who in his two or three last courses of lectures seemed to give it the preference. The most prudent part on this occasion certainly was, to wait till it could be determined by a greater number of facts, whether all the phenomena of chemistry might be explained by the theory of gases, without our having recourse to *phlogiston*. M. Macquer, sensible that a considerable revolution must necessarily take place in the system of chemistry in consequence of these discoveries, but thinking it impossible to account for all the phenomena without admitting the presence of an inflammable principle, substituted light in the room of *phlogiston*; as the existence of the latter had never been strictly demonstrated, while the influence of light on many chemical phenomena is a well known and undeniable fact.

Since the death of that celebrated chemist, the science has been enriched with a variety of discoveries, all

tending to confirm the new theory. The multitude of facts which I have been collecting during a period of twelve years, and the number of the experiments of other chemists, which, on a repetition of them, I have found to be attended with the same results, have finally convinced me of the justness of that theory, and have led me to consider those naturalists who still continue to maintain, with more or less keenness, the existence of *phlogiston*, as either unskilled in the science, or incapable of accuracy in their experiments.

C H A P. III.

Concerning the Chemical Attractions or Affinities.

IN the first chapter it was observed, that the means used in performing chemical operations, which have been arranged under the two general heads of Analysis and Synthesis, are imitated from Nature, who employs them in her operations. To illustrate that truth, we shall here explain what is understood by the chemical affinities.

A person cannot even enter upon the study of nature, without taking notice of that wonderful mutual force by which all natural bodies are attracted towards each other. On this great and universal law, all those phenomena depend which the philosopher contemplates with curiosity, and which even the most ignorant of men cannot behold without admiration.

This force, by which indeed the order of the universe is maintained, actuates the most minute bodies as well as the most enormous masses of matter. But it acts by laws, either essentially different, or at least differently modified, according to the mass, consistency, and distances, of the bodies subject to its influence. Without examining its effects on the planetary bodies, whose distances and motions it regulates; let us consider in what manner it affects the different parts of the globe which we inhabit, that we may by this means discover its laws.

Natural philosophy teaches, that when two solid bodies of the same kind come into contact, they adhere together with a degree of force proportioned to the extent of smoothness of the surfaces in contact. Thus, two planes of glass, or two sections of a ball of metal, if pressed together, unite with a degree of tenacity which renders a considerable effort necessary to separate them. This force produces all the phenomena observed in chemistry. It becomes, therefore, an object of the highest importance to study all its laws, and inquire what variations it undergoes from diversity of circumstances.

The greater part of chemists have denominated this force *affinity* or *relation* ; because it has been thought to depend on an analogy or conformity of principles in the bodies between which it subsists. Bergman has given it the name of *chemical attraction* : and though its phenomena are different from those of the planetary attraction first observed by Newton, yet, as both depend upon the same principle, we shall follow Bergman in the use of the name. Chemical attraction may take place between bodies of the same nature ; or between bodies of different natures. Let us consider it under these two points of view.

§ I. Concerning the Attraction or Affinity that takes place between Bodies of the same Kind, or the affinity of Aggregation.

WHEN two bodies of the same nature, for instance two globules of mercury, placed at a certain distance from each other, tend, by virtue of this force,

to unite, and do actually enter into union, they form a sphere greater in bulk, but precisely the same in weight. In that event, therefore, this force affects only the physical, or obviously apparent qualities of bodies ; it unites separate portions of similar matter ; by confounding together several distinct masses, it forms a body of greater bulk, and unites a number of separate parts into a *whole*. It is denominated the *attraction or affinity of aggregation*, in order to distinguish it from that which takes place between bodies of different natures. It produces an aggregate in which the physical qualities of the bodies united undergo a new modification, without any sensible change being produced in their chemical qualities. The *aggregate* is nothing more than a coherent body, the parts of which are retained in union by the force of aggregation. It must be distinguished from the mass called an *heap* ; for though an heap consists of parts all of a similar nature, yet those parts are disposed loosely, and without coherence. It is likewise to be distinguished from a *mixture* ; which consists of a quantity of dissimilar particles blended together without adherence. This may be farther explained by a familiar example : Flowers of sulphur, or sulphur powder, whose parts have no adhesion, and may be separated by the slightest effort, compose an heap, the parts of which are not affected by the affinity of aggregation. This mixed with another heap, with for instance consisting of nitre in powder, gives what is called a *mixture by confusion*. But if, by the help of friction and cooling, you subject this heap to the power of aggregation, the molecules or integrant parts of sulphur will then be drawn towards each other

its liquefaction, and will mix and unite in such a manner as to form, when cooled, an uniform mass or solid, which will be a true aggregate.

The force or affinity of aggregation exists in various degrees, which are measurable by the effort necessary to separate the integrant parts of any aggregate body. We shall distinguish aggregates into four kinds, under which all the bodies in nature may be arranged.

1. The first is the *hard or solid aggregate*, in which the integrant parts are united by a very considerable force, and cannot be separated without great exertion. This genus comprehends many species or degrees, from the hardness of the precious stones and of rock-crystal, to the yielding contexture of the softest wood. Its peculiar characteristic is to form a mass, the constituent parts of which cannot suffer any discernible motion without being divided.

2. Bodies whose constituent parts may be easily moved backwards and forwards, so as to change their relative situation, without being separated, belong to *the soft aggregate*. Less force is requisite to maintain the cohesion of a soft body than to preserve the consistency of a solid aggregate; and less reaction to destroy it.

3. *The fluid aggregate*. Its integrant parts are so slightly united, that the gentlest effort is sufficient not only to change their relative situation, but even to divide them into distinct globules.

4. Lastly, the *aëriform aggregate*, the tenuity of whose integrant particles renders them imperceptible, and in which the affinity of aggregation is the least

possible. The air of the atmosphere affords an example of this.

These four kinds of aggregate are, properly speaking, but different degrees of the same force : but it is absolutely necessary to distinguish them accurately from one another ; because they have an important influence on the operations and phenomena of chemistry, which is diversified according to their differences : yet it may be proved in the most satisfactory manner, that they are only so many different degrees of the same force ; for many bodies are capable of assuming each of these four states successively. Water, in the form of ice, is a solid aggregate ; its hardness is greater in proportion as its temperature is lower ; when exposed to the temperature of 32° Fahrenheit, it assumes a kind of softness * before passing into a fluid state. Its existence in this last state is universally known : and philosophers have calculated what degree of expansive force is necessary to reduce it to vapour ; in which state it becomes an aëriform aggregate. Metals, grease, concrete oils, wax, &c. may be in the same manner made to pass through these several states of aggregation.

The more particularly any person is acquainted with the laws of chemical attraction, so much the more will he be convinced of the importance of distinguishing between these several kinds of aggregation, and estimating each of them aright. Accurate ideas concerning each of them are essentially necessary to enable us to compare this with the second species of chemical attraction, which will come next to be examined.

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* A doubt expressed by the translator of the second edition, induced me to repeat this experiment ; and I found that M. Fourcroy had by no means misrepresented the fact.—H.

As these two kinds of affinity, though they appear to depend on the same cause or principle, yet in all the phenomena of chemistry seem to act in direct opposition to each other (for it may even be inferred from facts which shall be related, that they are in the inverse ratio of each other), it is absolutely necessary for the chemist to weaken or destroy the one, when he wishes to effect any operation by means of the other. Now, the attractive force of which we have been speaking, is almost always that which he has occasion to diminish; and it likewise admits of various modifications by the power of art.

All that is necessary to destroy or weaken the affinity of aggregation, is, to oppose to the cohesion of the aggregate an external force more than sufficient to counterbalance that which preserves the union of its component parts; and the external force applied must therefore be proportioned to the cohesion of the parts. This is the great law to be always observed in the preparatory operations; the sole purpose of which is to destroy the affinity of aggregation. Pulverization, grinding, rasping, filing, and cutting, are so many means for counteracting the cohesion of bodies and dividing their constituent parts. Heat and evaporation produce the same effects on fluids, and on those solids which are susceptible of dilatation or fusion. But these last mentioned operations being effected by heat, come properly under the second species of chemical attraction; as does also the solution of bodies by water.

As art can apply a great variety of means to counteract, and even destroy the force of aggregation; so it likewise affords others to restore it, and cause it to

act with all its former energy. All the manipulations which it employs for this purpose, consist in placing the bodies, whose force of aggregation is to be restored, in such a state of division and fluidity, that their particles may be at liberty to obey the power of attraction, by applying to each other those of their surfaces which are best adapted to unite; and they thus form a new aggregate, which, in regularity of figure and cohesive force, is generally equal, and sometimes superior, to natural aggregates of the same kind. We may take this opportunity to observe, that all aggregate bodies may be divided by their figure into two classes, Regular and Irregular. Every body in nature appears under the one or the other of these two forms; and art, which always emulates, and sometimes even rivals, nature, can produce at pleasure a regular or an irregular aggregate. All substances capable of passing through the several states of aggregation above enumerated, but more especially salts and metals, may be so managed during the process by which they are reduced from a fluid to a solid state, as to assume the form either of an irregular mass, or of a body with regular lines, angles and surfaces, which is called a crystal. The first form is obtained by keeping the particles of the fluid body, whether its fluidity may have been occasioned by fire, or water, very near to each other; and causing the liquefaction to cease suddenly, so that they may come into contact all at once, and the affinity of aggregation may cause them to unite into one solid mass. But, on the contrary, to produce crystallisation, it is necessary to keep the parts of the body which you wish to bring into that state, at as great a distance as possible from

one another, that they may remain for some time in a kind of equilibrium, before coming into union, and may present to each other such of their surfaces as are best adapted to unite. From this it appears, that crystallisation is entirely owing to the affinity of aggregation; and if the phenomena of crystallisation be observed with a proper degree of attention, they will afford an idea of the manner in which the affinity of aggregation acts. For this purpose it is mentioned here: it will be more particularly explained under several future articles of this work.

§ II. Concerning that Species of Chemical Attraction which unites particles of different Natures; or the Affinity of Composition.

WHEN two bodies differing in nature have a tendency to unite, they enter into combination by virtue of a power somewhat different from that which we have been considering: it has been denominated *the affinity of composition*; but may be with more propriety named *the attraction of composition*. This species of attraction or affinity is of still greater importance than the former, as it acts in all chemical operations, and none of these can be explained without it. The existence of this power has been always known; but it was not observed with the attention which it justly merits, till such time as it appeared to affect the practice no less than the theory of the science of which we are treating. A knowledge of this affinity is essentially necessary to direct the practitioner who pursues a train of experiments, as well as the philosopher who

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collects and compares facts. This is the compass by which both must steer; and it may be affirmed, that whoever is well acquainted with the laws of chemical attraction, is acquainted with the extent and sublimity of the science.

Convinced of this truth, we shall here make it our business, first, to exhibit faithfully all the facts which can serve to illustrate the nature of this affinity; and, next, to give an account of those hypotheses which have been formed to explain its cause.

Observation, the parent not only of chemistry but of all experimental science, has shown, that the attraction, or affinity of composition, presents certain invariable phenomena; which may be considered as laws established by nature, and which can escape the observation of none but such as are incapable of examining them with due attention. These laws, founded on a vast variety of well-established facts, may be reduced to eight; which are as follows,

I. First Law of the Attraction of Composition.

The attraction, or affinity of composition, cannot act but between bodies of different natures.

This first law is invariable, and admits of no exceptions. That two bodies may combine, and form a compound, it is indispensibly necessary for them to be different in kind. Join two bodies of the same nature, and you form only an aggregate, of which the bulk and extent are enlarged, but its essential properties remain unaltered; and their union is occasioned and preserved by

by the affinity of aggregation, conformably to the explanation already given of the nature of that affinity. Thus, two pieces of wax, resin, or sulphur, may be united by the action of heat ; and this instance is sufficient to explain the difference between aggregation and composition.

This law holds so invariably, that the attraction of composition is never stronger than when the bodies between which it acts are, in nature, the most essentially different from one another. Thus acid salts and alkalis, though the properties of the one are directly opposite to those of the other, enter into the most intimate mutual combination, and form the most perfect compound. The same opposition subsists between the properties of alkalis and sulphur, of acid salts and oil, of acids and metals, of water and spirit of wine, &c. ; all which substances have a strong tendency to mutual union.

It is the more necessary for us to gain an accurate knowledge of this great law of the affinity of composition, because a number of chemists, with Stahl at their head, have laboured to prove, that bodies never enter into combination, but in consequence of a certain relation, or resemblance between their properties: an opinion to which no person will agree who knows the full extent of this primary law. When reading the reasonings even of the most eminent chemists on this subject, we cannot avoid observing, that the relations which they labour to point out between those substances which have the strongest tendency to mutual union, appear always extremely remote ; and that, by the same means, resemblances might be easily found out between bodies the most dissimilar. It is easy to see, however, that th

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ingenious men have proposed this theory, merely from desire to simplify and illustrate the doctrine of chemical attractions: and those who are sensible of the difficulty of establishing systems in any of the departments of human knowledge, will always consider them as entitled to the gratitude of every friend of science. Their labours have not been without their use, as they have collected a number of facts, and pointed out their connections. But a regard to truth, which it becomes us to prefer to every other consideration, obliges us to confess our ignorance of the cause of this important phenomenon, instead of referring it to an analogy, the existence of which is inconsistent with those ideas of the properties of bodies which we derive from experiment.

II. *Second Law of the Attraction of Composition.*

The attraction of composition acts only between the minutest particles of bodies.

IN order to form a just idea of the nature of this law it is necessary for us to distinguish chemical from physical subjects. These last are bodies whose external qualities, such as weight, bulk, surface, extent, and figure, are perceptible to our senses, and may be estimated by their effects upon them. Aggregates are the bodies whose qualities are observed and compared by the naturalist. Chemical subjects, again, are substances which have lost their aggregation; and which, of consequence, no longer present to the senses the physical properties of aggregates. They are minute particles the extent of which cannot be measured, nor their bulk or form distinguished. It is not till after bodies have
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been reduced to this state of tenuity by the several preparatory operations above-mentioned, that they become subject to the affinity of composition; and the chemist cannot cause them to enter into combination, without presenting them to one another in a state of division. This force seems to actuate none but the minutest particles of bodies: and in this manner does the attraction of composition appear to differ from that which acts between large masses of matter. The difference is still more striking when we consider the constant opposition between the attraction of aggregation and that of composition. This opposition is so invariable, that we may even venture to advance it as a chemical axiom, that the attraction of combination is in the inverse ratio of that of aggregation; these two forces being always in opposition, and forming a kind of counterpoise to each other. The attraction of aggregation always resists the combination of different bodies; where it acts with the greatest force, they have scarce any tendency to mutual union; and again such substances as are the least under the influence of the force of aggregation, have a strong tendency to combine with others. The various kinds of gas, or air, for instance, of all known substances are the least under the influence of the force of aggregation; and of them there are many whose tendency to combination is so strong, that they combine with the greatest facility with almost any natural body. Yet we shall afterwards see that this happens only when the heat which enters into the composition of elastic fluids is but slightly combined with a base; and that the aëriform state often occasions a contrary tendency; as for instance, in pure air.

III. Third Law of the Attraction of Composition.

The attraction of composition can unite more bodies than two.

THIS law of chemical attraction is one of those which have been established by the fewest observations; as we are still but very imperfectly acquainted with its extent. We are acquainted with a vast variety of the combinations which are produced by the union of two bodies; with a few which are formed by the union of three bodies; but we know of scarce any instances in which four different bodies have an equal tendency to enter into mutual combination, and remain in this state. Metals are the only bodies that are known to be capable of this last species of combination; and of which two, three, or four, may be effectually blended together. It is highly probable that there are in nature combinations made up of more than four bodies, of five or eight, for instance; but with such we are hitherto unacquainted. The reason why so little progress has been made in the study of this law, shall be explained when we come to treat of the eighth law of the affinity of composition. The number of the substances of which any composition consists is denoted by saying, the affinity of one, two, three, or four bodies, and so on. The rapid progress which chemistry has of late begun to make, the multiplicity of its researches, the variety of the objects to which these are directed, and the scrupulous accuracy of observation with which they are conducted, afford us reason to hope that those affinities which are named *complex* will soon be better known.

IV. *Fourth Law of the Affinity of Composition.*

That the affinity of composition may take place between two bodies, at least one of the two must be in a fluid state.

THIS law has been long known to chemists, and has been long expressed in this axiom, *Corpora non agunt, nisi sint soluta*. Uniform and accurate observation has shown that two solid substances can never enter into mutual combination. Even bodies which have the strongest tendency to unite, cannot be brought into union till either the one or the other of them be reduced to a fluid aggregate. Bodies enter into combination with more or less facility, according as they are more or less in a state of fluidity, and consequently possess more or less aggregative force: and therefore no two bodies enter into combination with such rapidity as any two of the saline aëriform fluids; for instance the muriatic acid gas and the alkaline gas.

Though no two solid bodies can enter into combination with each other; yet in some instances dry substances, reduced into a fine powder, re-act upon each other with so much energy, as to unite and form a new compound. Thus I have discovered that caustic fixed alkali, when reduced by trituration, unites in a cold dry state with sulphur, antimony, and kermes, as I shall elsewhere more particularly relate: but in this instance, the reduction of the bodies into their most minute particles by pulverization, and the moisture of the atmosphere attracted by the salt, which soon deliquesces, have a considerable share in effecting the combination;

phenomenon takes place, to which chemists have given the name of *solution*. It consists in the attenuation, and entire destruction of the solid body in contact with the fluid. The cause of this phenomenon is, the attraction of combination between two substances, of which one is a liquid, the other a solid, such as sulphureous acid, and a bit of calcareous spar, is greater than the aggregative force which preserves the cohesion of the solid in exclusive union with one another. Since, by the third law, this species of attraction acts but on the most minute particles of bodies, they must necessarily lose their aggregation, and be reduced to very small particles, in order that it may unite with the *sulphuric* acid, and form *calcareous*. Formerly, chemists always distinguished between the body which effected and that which suffered the action: the former was the fluid, the latter the solid. Modern chemists refuse to admit this distinction, and suppose a force in the fluid superior to what exists in the solid aggregate. M. Gellert was the first who showed that the two bodies contribute equally to the solution; and that in the above instance, the vitriol could not destroy the aggregation of the spar, but the spar has a tendency to unite with the sulphuric acid less strong than that of the acid to combine with the vitriol. The name *solvent*, therefore, given at present to fluids, is not strictly chemical, as it conveys only the idea

chanical operation ; and it were better to lay it aside. But since it has been unluckily introduced, the student of chemistry must always remember, that when one body is said to dissolve another, no more is meant than that the former is in a fluid state, and that the fluid can never possess greater activity or energy than the solid ; but the solid may rather be considered as possessing these qualities in a superior degree, since its tendency to combination is so powerful as to overcome its aggregative force.

The false idea of solution which has prevailed till of late, arose no doubt from the mechanical theory by which some philosophical chemists have sought to explain this operation of nature. This theory, which appears in every page of Lemery's chemistry, consists in considering the solvent, an acid, for instance, as an assemblage of very acute points, and the body to be dissolved, as containing a vast number of pores, into which the points of the acid insert themselves, so as to disjoin the particles of the body, and reduce them to that state of division in which the aggregate disappears. To mention this opinion is, at present, all that is necessary to show its absurdity and inconsistency with those laws which accurate observation has established in the experimental sciences.

V. Fifth Law of the Attraction of Composition.

When two or more bodies are combined by this affinity, their temperature suffers a change at the instant of their union.

THIS phenomenon so invariably attends all the combinations effected by art, that we cannot help consider-

ing it as one of the laws of the attraction of composition. The temperature of bodies may be altered in two ways: new combinations sometimes produce cold, sometimes heat. The latter is oftener produced than the former, but as cold is certainly produced in several synthetic operations, we have thought proper to express this phenomenon by the general term, Change of temperature.

It may be objected, that in certain solutions or combinations which are slowly effected, no change of temperature is perceived: But we would desire persons who are disposed to offer such an objection, to immerse a good thermometer into those solutions, and they will not fail to be convinced that a change of temperature is produced. It appears from some valuable observations by M. Baumé, which shall be elsewhere more particularly mentioned, that this phenomenon is occasioned by the change of aggregation, which the bodies entering into combination undergo as they pass from a solid to a fluid state. But as that change is produced by the action of the affinity of composition, both the one and the other evidently depend on this principle.

Macquer has given it as his opinion, that the variations of the temperature of bodies entering into combination, are occasioned by the motion of their component particles: but though we should admit this as an happy account of the cause of the heat produced in new combinations, still the cold which takes place in some of them remains unexplained. Several modern chemists, particularly Scheele and Bergman, consider heat as a distinct body, acting a principal part in all chemical combinations; and assert, that change of temperature arises from the absorption or disengagement

ment of this body. This theory affords a good explanation of the cause of that change of temperature which takes place when a new combination is produced.

VI. Sixth Law of the Attraction of Composition.

Two or more bodies united by the attraction of composition form a substance, the properties of which are different from those which each of the bodies possessed before their union.

It is of importance to establish the existence of this law; because many celebrated chemists of the present age, have entertained opinions concerning the properties of compounds, which to us appear inconsistent with a great number of facts, and are directly contradictory to what we here offer as one of the principal phenomena of the affinity of composition.

Stahl and his followers, whose genius has, in other instances, rendered so many important services to chemistry, have asserted, that compounds always partake of the properties of those bodies of which they are compounded, and possess a kind of middle nature between their principles. They have even carried this notion so far as to persuade themselves, that it is possible to determine the peculiar properties of any principles, by examining the compound formed by their union. Thus, Stahl pronounced salts to be a compound of earth and water, because he thought he could distinguish their properties to be intermediate between the properties of these two substances. As we are to

principle ; and to some of them when combined acids, &c. *.

The consistency of bodies is also affected by combination ; the consistency of a compound being most always different from that of either of the bodies of which it is composed. Thus, two fluids produce a solid by their combination ; for instance the sulphuric acid united with a solution of potash. And again, a fluid often results from the combination of two solids ; as from a combination of neutral salts with ice, and from the mixture of an amalgam of silver with an amalgam of bismuth. But the quality which suffers the most frequent alterations in the combination of bodies is colour. Sometimes it is lost : thus the coloured muriatic acid, combined with a metal, becomes white. But it oftener happens, that two bodies of different tints of colour, assume when united either a fainter or a stronger colour, as when iron or copper are dissolved in almost any of the acids, and when the calces of mercury, or almost any other metal, are united with oxygen.

Many bodies, which in a simple state, are strong and odorous, become inodorous when brought into combination ; as for instance, muriatic acid gas and ammonia or alkaline gas, which in a simple state have a strong suffocating smell, form in combination ammonia.

* We cannot avoid making use of terms and denominations which have not been explained. But the reader may have recourse to the table subject to the end of the last volume, and to the beginning of our account of the several articles to which such names belong, for an explanation of them. This inconvenience, though it may perplex the beginner, cannot be otherwise obviated.

cal muriate, a neutral salt that has scarce any smell. Again, from the union of two indorous bodies, there often results a strong-smelling compound ; sulphur and fixed alkali, each of which is in a simple state almost destitute of smell, form, when united, liver of sulphur, or *fulpbure*, a substance which in a moist state is extremely fetid.

The fusibility of bodies is subject to the same changes. Two substances, not susceptible of fusion, or which cannot be reduced to that state without the greatest difficulty, when combined acquire the property of fusibility in an high degree. Combine sulphur with any of the metals, and you will have a striking instance of the truth of this assertion. A variety of other facts, beside those which have been here adduced, concur to establish this law in contradiction to the theory of Stahl.

VII. *Seventh Law of the Attraction of Composition.*

The attraction of composition is measurable by the difficulty of destroying the combination formed between two or more bodies.

CHEMISTS know how to separate bodies in union, however strong their natural attraction or adherence ; but the means which they employ for this purpose are more or less easy, more or less complex. It has been uniformly observed, that in proportion as a compound is more or less perfect, its component parts are separated with more or less difficulty : And the degrees of the difficulty with which any two substances are se-

tion is formed, consisting of the acid and the alkali. This decomposition is commonly known by the name of *precipitation*; because the substance separated generally sinks to the bottom of the fluid compound.

The substance that sinks to the bottom of the vessel in which this operation is performed, is named a *precipitate*. The substance by the addition of which the phenomenon is produced, is denominated the *precipitant*. There are four different kinds of precipitates: *A true precipitate* is formed, when the substance which sinks to the bottom is one of the principles of the compound decomposed by the addition of the new body. When sulphate of lime, which is a combination of lime and the sulphuric acid, is decomposed by means of potash, which substance has a greater affinity with the acid than with lime, the lime being separated falls to the bottom, and constitutes a true precipitate. *A false precipitate* is produced, when the new combination of the precipitant with one of the two simple bodies of the compound which it has decomposed, falls to the bottom on account of its insolubility, while the separate body remains in a state of solution. When *mercurial nitrate* is decomposed by the muriatic acid, with which the oxide of mercury has a stronger affinity than it has with the *nitric acid*, the new combination of mercury with the muriatic acid sinks to the bottom of the mixture, forming a false precipitate, above which the nitric acid remains dissolved in the water. This phenomenon depends entirely, as shall be elsewhere shown, on the different degrees of the solubility of the different substances.

We cannot avoid observing, in this second order of
precipitates

precipitates, an error of denomination which may tend to mislead beginners. For, if this name be given to the substance separated from the compound by the precipitant, it cannot with any propriety be applied to the new combination then formed. But though we should even confine the term *precipitate* to denote the substance separated by the precipitant, it might still occasion mistakes; as it happens in many cases that the insulated substance, instead of sinking, rises and is volatilized. Thus, when the combination of the muriatic acid with volatile ammoniac or alkali, known by the name of ammoniacal muriate, is decomposed by quicklime, with which the acid has a greater affinity than with volatile alkali, the alkali evaporates, and the mixture affords no appearance of any precipitate.

In order to produce these precipitates, it is necessary that the substances be in a liquid state: The process is then called precipitation effected in the humid way, to distinguish it from that which is accomplished by the action of fire, or in the dry way, either by means of fusion or distillation; which operations shall be hereafter particularly explained.

Modern chemists have likewise taken notice of two other species of precipitate; the distinction between which is much more just and useful than that between the preceding. These are *pure precipitates* and *impure precipitates*. The first comprehend all bodies which, after their separation from those compounds into which they entered, exhibit all their original properties, without appearing to have suffered any alteration, in consequence either of existing in a compound state, or of being exposed to the act of decomposition. The precipitates

precipitates of this species are very numerous, but the impure precipitates still more so.

In order that precipitates may be obtained very pure it is requisite that they should have suffered no alteration by the action of the bodies with which they were combined before their precipitation ; and that there subsist no affinity between them and the substance employed to precipitate them. For instance, when *alcohol*, or spirit of wine, is poured into a solution of sulphate of potash the spirit of wine having a stronger affinity with the water than the water has with the salt, the latter is left in a separate state, and becomes a pure precipitate because it has suffered no alteration from the water and has not the most distant affinity with the alcohol. But when two bodies by combination have produced mutual alterations on each other, as happens in the combination of acids with metals, the third body, such as an alkaline salt, employed to effect a separation between them, will give the metal in a state very different from its original character, and will thus produce an impure precipitate. The same result takes place when the precipitant has any tendency to unite with the precipitate : thus, in the above-mentioned instance of a metallic solution decomposed by an alkali, part of the alkali entering into combination with the metallic oxide renders it an impure precipitate. These two causes of the impurity of precipitates are almost always found to act together. We can sometimes distinguish at once whether a precipitate be pure or impure, by adding a much greater quantity of the precipitating body than is necessary to decompose the compound. This extraordinary quantity then enables the precipi-
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of Composition.

tant to combine with the precipitate, if there be any affinity between them, and dissolves the latter so entirely as to make it disappear. If a quantity of volatile alkali or ammoniac be poured upon a solution of copper with the nitric acid, the copper is precipitated in the form of light blue flakes. The colour of this precipitate, so very different from the natural brilliancy of copper, shows it at once to be an impure precipitate: If we add more ammoniac, this will still more plainly appear. The blue flakes are again dissolved by the salt, the fluid becomes gradually homogeneous and transparent, and assumes a very fine deep blue colour; a sure proof of the combination of the oxide of copper with the alkaline salt.

For our present accurate knowledge of these impure precipitates, which occur much more frequently than the pure, we are indebted to the researches of M. Bayen, concerning the decomposition of mercurial solutions by alkalis, and the state of the mercury precipitated in this operation.

It is now easy to understand the theory of the decomposition of compounds of two bodies by means of a third brought into contact with them: they all depend upon simple elective attractions.

But beginners will find more difficulty in acquiring a distinct idea of that complicated phenomenon to which chemists have given the name of *double elective attraction*. It often happens that a compound of two bodies cannot be destroyed by a third or fourth body individually; while, if a compound of the two last be brought into contact with the first compound, both compounds are instantly decomposed. An example
will

will make this better understood: Sulphate of potash, or a combination of the sulphuric acid with potash, cannot be decomposed by either quicklime or the cold nitric acid individually; but pour into a solution of the former neutral salt a proper quantity of the *calcareous nitrate*, formed by the union of the nitric acid with quicklime, the two combinations will be mutually decomposed; the nitric acid uniting with the potash to form common nitre, while the sulphuric acid uniting with the lime, forms sulphate of lime; which being less liable to solution than the nitre, is therefore precipitated. This affinity may possibly appear strange and unaccountable; but it may be explained in the following manner: The sulphuric acid cannot be separated from potash, either by lime or by the nitric acid, because it has a stronger affinity with that alkaline substance than either of the two latter bodies have with it or with the alkali. But when you present to the sulphate of potash a compound of the nitric acid with lime, the nitric acid immediately exerts its tendency to combine with the potash, while the sulphuric acid is at the same time attracted by the lime; so that the decomposition of the sulphate of potash is begun by the action of the nitric acid, and completed by that of the lime. To explain this double affinity still more clearly, let us suppose the force of adhesion, which unites the sulphuric acid with potash, to be equal to eight; the nitric acid tending to unite with that alkaline substance with a less degree of force, which we may estimate at seven, would be insufficient of itself to decompose the sulphate of potash; but the lime by its tendency to combine with the sulphuric acid, aids it with

a force which we may consider as equal to six ; and these two forces together amount to thirteen ; which sum of forces is exerted against the force eight, to separate the sulphuric acid from the potash. This compound force will also be greater than that which maintains the union between the lime and the nitric acid.

There are therefore two kinds of attraction in double elective attractions, which must be carefully distinguished from each other : 1. The first is that by virtue of which the principles of each of the two compounds adhere to one another, which in the above instance retains the sulphuric acid in union with the potash, and causes the nitric acid to adhere to the lime. I shall follow Mr Kirwan in giving to this force the name of *quiescent attractions* ; because its tendency is to preserve the two compounds in their first state. 2. The second is that by which the four principles of the two compounds reciprocally change their situations, and are combined in a different order : it is by virtue of this affinity, that in the above instance the potash combines with the nitric and the lime with the sulphuric acid. This second force I shall here denominate *divellent attractions* ; because it counteracts and destroys the first. From this useful distinction, it becomes easy to explain the cause of this double decomposition, by exhibiting in a table, as Bergman has done, the forces of the attractions by which it is produced. Place the two compounds which mutually decompose one another between two braces directly opposite, the acids standing in opposition to the bases on which they act ; between these four bodies note down the particular degrees of the attractive force which they exert upon each ; add together the two horizontal num-

bers, expressing the quiescent attractions ; add also vertical numbers which are employed to mark the violent attractions : if the sum of the latter exceed of the former, a double decomposition and a double combination will be effected. The usefulness and accuracy of such a table may be shown at once by giving an ample of it in the last mentioned compounds.

E X A M P L E.

	Nitro, or nitrate of potash.			
	Potash	7	Nitric Acid.	
		divell. atrac. 6		
Sulfate of Potash.	8 quiescent	attract. 4 = 12		Calcareous Nitrate
	Sulphuric Acid.	11	Lime.	
		13		
	Sulfate of lime *.			

Chemists have but lately begun to take notice of these double elective attractions ; and we are far from knowing them all. Those who are engaged in chemical researches will frequently observe this kind of composition in circumstances where no such phenomenon was before suspected to take place. In the history of saline substances we will repeatedly have occasion to take notice of several of those double elective attractions

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* I have given ten similar examples of double decompositions which take place in the mixture of neutral salts, in two dissertations ; which the reader may consult. See my *Memoirs and Observations on Chemistry* Vol. I. 8vo, Paris, 1784, pages 308 and 438. E.

which have been lately observed by Bergman, Scheele, &c. and by ourselves.

Before concluding our account of this tenth and last law of the attraction of composition, we cannot help taking notice of an ingenious method contrived by a French chemist, to exhibit at once all the more regular phenomena of chemical decomposition. Geoffroy the elder, observing the various relations which subsist between different bodies, and the precipitations produced in consequence of those relations, with more attention than had been applied to that object by former chemist, contrived, in the year 1718, to exhibit them in a table; in which he arranged those bodies whose affinities he had observed, in the order of their affinities. We only mention that ingenious contrivance in this place; but will have many future occasions in the course of this work, of explaining it more particularly. Geoffroy gave that table only as a first attempt, to which he well knew much might be added. A number of chemists have adopted and enlarged his plan. Rouelle the elder made some corrections on his table, and added several columns to it. M. de Limbourg, a physician at Spa, in an excellent dissertation on the affinities, which, in conjunction with another by M. Sage of Geneva, gained the prize offered in 1758 by the academy at Rouen, has formed one still more extensive. M. Gellert, in his *Metallurgic Chemistry*, has likewise given a new table of affinities. But none has contributed more to the advancement of this part of the science than Bergman, professor of chemistry at Upsal; whose labours have been so beneficial to the science in general. That celebrated chemist has followed M. Baumé, in distinguishing the

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attractions

attractions which operate in the humid way, from the which effect combinations in the dry way. He has given two very extensive tables, in which he exhibits the elective attractions of a vast number of natural bodies. To the same philosopher we are indebted for a very ingenious table, in which he has found means, by a particular disposition of the chemical characters, to express the phenomena of double elective attraction: Of this we gave an example above,

After giving this view of the leading phenomena of chemical attraction, and unfolding the laws by which that force appears to be regulated, we must observe that in some cases these laws seem liable to certain variations. We need not here mention all the facts on which this assertion is founded, as we shall be careful to take notice of them wherever they occur; only we may observe, that these seeming anomalies of chemical attraction arise from the influence of particular circumstances; such as the quantity of the substances, the temperature of the atmosphere, motion or rest, solution by water or fire, that is, in the humid or in the moist way, the state of aggregation proper to each body, &c. Bergman has considered all these circumstances with peculiar care; and has shewn how far they may be expected to vary the laws of attraction. From the various facts which he has collected relative to this subject, he concludes, that their variations can be regarded only as exceptions, by no means sufficient to weaken the evidence on which the doctrine of chemical attraction is founded.

We are led to consider two other species of affinity that have been admitted by some authors, in the same light,

light, the affinity of *intermediates* and the *reciprocal* affinity. By the first, they understand that by which bodies, which have no natural tendency to mutual union, are capable of being united after one of them has been combined with a third body, which serves as an intermediate between them: Oil, for instance, does not combine with water; but a combination of oil with a salt constitutes a soap, which is soluble in water, the salt acting as an intermediate. But it is not the salt which renders the soap soluble, for its properties are entirely lost in the soap; the solubility of this compound in water is owing to the new properties it has acquired. This phenomenon falls evidently under the sixth law of chemical attraction; by which it is established, that compounds acquire new properties totally different from those of their component principles.

The *reciprocal affinity* takes place when a compound consisting of two bodies is decomposed by a third, and the separated principle again decomposes the new combination; so that the principles seem to act reciprocally. The sulphuric acid has a greater affinity than the nitric acid with potash, and accordingly decomposes a combination of these two principles; but the nitric acid, when left in a separate state, has power to divide the sulphuric acid from the alkali; for by heating sulphate of potash with the nitric acid, nitre is again obtained. This kind of affinity, admitted by M. Baumé, is occasioned by two circumstances, whose influence disturbs the general laws of chemical affinity. The common nitric acid must be heated before it can decompose sulphate of potash; and the nitre obtained by this process is again decomposed by the sulphuric acid, as soon

as the mixture returns to a cold state. The fuming, or *nitrous acid*, decomposes sulfate of potash cold; the fuming spirit of salt or muriatic acid effects the same decomposition, according to M. Cornette: but Bergman has very properly observed, that the odorating and fuming acids, which he calls *phlogisticated*, have affinities different from those which belong to them in their simple state. Besides, in these cases but a very trifling part of the salt is decomposed.

In all these instances, the order of the elective attractions is changed and modified by particular circumstances. The rest of the facts on which Mr Baumé establishes the existence of the reciprocal affinity, such as the decomposition of ammoniacal muriate by chalk, and of calcareous muriate by *concrete volatile alkali*, come properly under the double affinities; as shall be shown when we treat of those salts.

All that now remains to be said on chemical attraction is, to give some account of the different opinions which have been advanced by philosophers concerning the cause of this force*.

The first who attempted to form a theory on this subject, thought that it must arise either from the elementary particles of bodies being all of the same form, or from the physical configuration of the parts, or lastly, from some occult relations of their intimate composition. These notions proceeded naturally from the mechanical explanations which were applied to all the phenomena

* That beautiful general fact, *that all particles of matter, which are susceptible of union by chemical affinity, continually tend to form bodies of a polyhædral, constant, and determinate form*; appears to have been sufficiently ascertained by Linnaeus, M. Romé de Lille, and the Abbé Hany; to deserve a place among the laws of chemical attraction—H.

phenomena of nature, in the infancy of the science of natural philosophy.

Most of the modern chemists who have attempted to explain the cause of chemical attraction, have observed a remarkable analogy between this force and the general attraction discovered by Newton. Considering nature as simple and uniform, they have been led to conclude, that the power possessed by bodies of entering into mutual union, must depend on the same general laws as that by which all bodies are attracted towards each other. They have compared the minute bodies on which the force of affinity acts, with those enormous masses which compose the system of the universe; and have ventured to affirm that it is the force of gravitation which causes the former to approach each other, and enter into combination. Several persons, adopting this opinion, but modifying it in a particular manner, have concluded, that chemical attraction was in the ratio of the gravity of bodies, and that those bodies which were of the greatest specific gravity possessed always the strongest affinities. This hypothesis is sometimes indeed justified by facts, and agrees with the affinities of many of the acids; but is contradicted by the phenomena of a vast number of decompositions, particularly of all those in which metallic substances are concerned. Some chemists have been even so strongly persuaded of the existence of an analogy between the attraction of large bodies and chemical attraction, as to imagine it possible to measure and calculate the former in consequence of our knowledge of the latter. M. de Morveau, whose opinions are likely to have considerable weight with other chemists, has made a num-

ber of experiments with a view to prove the the above assertion. Applying to a surface of plates of metal of the same diameter, suspended in one arm of a balance, the other arm of which carried the next put weights into the dish sufficient to support the plate of metal over the mercury; and he actually by making comparative trials of different metals, that these adhered to the mercury with different degrees of force, proportioned to the affinities known to exist between them and that substance. Gold adhered with the greatest force to the mercury, a greater weight being necessary to raise it than to raise any of the other metals: Cobalt, again, which is known to have no affinity with mercury, seemed to have no adhesion to that surface, and was elevated above it with the greatest ease. But we must use the freedom to observe that from several circumstances, such experiments may be in some degree fallacious: the inferior surface of the smooth plates of metal applied to the mercury cannot but combine with that substance; an amalgam formed by this event being more or less according to the ease or difficulty with which the metal unites with the mercury, this combination increases the weight of the plate, and renders a greater weight requisite to raise it above the mercury. A plate of metal adhering to a surface of mercury, cannot be raised above it without dividing the mercury into particles; so that the force necessary to raise this plate is employed rather in overcoming the mutual adhesion of the particles of the mercury, than in dividing the mercury from the metal.

It must be acknowledged then, that if c

attraction be the same with general attraction ; yet the difference of the laws by which these two forces are regulated, proves the former to be a particular modification of the latter. This truth becomes evident from a comparison of those laws of the Newtonian attraction with which we are acquainted, with the general facts relative to chemical attraction which have of late been discovered: The former acts only upon large bodies, and in the direct ratio of their masses ; the latter affects only minute bodies, and has absolutely no influence on such as are of any considerable bulk. Attraction acts between bodies placed at an immense distance from each other : affinity never acts but between bodies in mutual contact. In describing the laws of chemical attraction, we have laid before our readers the facts on one side of this comparison : and we are induced to conclude, that the phenomena which these two great laws present, are still so strikingly different, as to render it highly proper for philosophers to distinguish between them *.

C H A P.

* I cannot help observing here, that the only true and precise definition of chemistry ; and which, so far as I know, has hitherto been given by no writer or lecturer on that subject ; is the following ; **CHEMISTRY IS THAT SCIENCE WHICH INVESTIGATES THE MODIFICATIONS OF THAT ATTRACTION WHICH TAKES PLACE ONLY BETWEEN THE MINUTE, COMPONENT PARTICLES OF BODIES.—H.**

C H A P. IV.

Concerning the Principles of Bodies.

IT has been the opinion of philosophers in all ages that notwithstanding the vast diversity of the bodies of nature, they are all composed of a few primary simple substances; and to these they have given the name of *Principles*. The analyses of chemistry, which afford the strongest facts in proof of this doctrine, having enabled chemists to form pretty accurate notions concerning the nature and differences of those principles; they have admitted several kinds of them. But it must be remarked, that they have taken the word *principles* in an acceptation different from that in which it was used by the philosophers of antiquity. Aristotle and Plato applied the name *principles* to a class of substances, which being of such subtlety as to escape the observation of the senses, constituted, as they thought, by their union, those bodies of a less simple nature, and perceptible to the senses, which still continue to be known by the name of *elements*. These are the same substances which have been by others philosophers denominated *atoms*, or *monads*. But chemists, not presuming to extend their speculation to such sublime and subtle objects, comprehend under the general name of *principles*, all those substances, whether simple or compound, which they obtain by the analysis of bodies. But as the principles of
bodies

bodies, when considered under this point of view, must be extremely various, they have divided them into *proximate* and *remote*. The first are obtained by a first analysis, and are capable of being resolved into other principles; thus, by decomposing a vegetable substance, we obtain oils, mucilages, salts, and coloured particles; all which are proximate principles of the vegetable substance, and each of them may by a new process be decomposed into other principles. By remote principles, they understand those substances which, being simpler than the proximate, enter into their composition. Thus, mucilage, one of the proximate principles of vegetables, affords by a new process, oil, water, earth, &c. and these are the remote principles of the vegetable. These two kinds of principles have been also distinguished by other names; such as *principiated*, applied to the proximate principles; and *principiant*, to the remote. These epithets distinguish the former as arising from the combination of other simple principles; and the latter, as serving by their union to constitute bodies, which though of a less simple nature, may yet become the principles of new compounds. Some chemists, to render these distinctions more just and accurate, admit more than two kinds of principles: They call those principles which appear so simple as to be incapable of farther decomposition, *primary*, or principles of the first order: *secondary* principles are formed by the combination of the *primary*; the combination of the *secondary* constitutes *ternary* principles; and these united in a new composition, afford *quaternary* principles, &c.

compounds. Lastly, Paracelsus applied the word earth to all those fixed, dry, and insipid, residues which are obtained in most operations, and are now known to be very different in their natures.

Beccher, who has treated of the science of chemistry in a very philosophical manner, being aware of the objections to which this system of Paracelsus was liable, and convinced of its inaccuracy, attempted to distinguish the elementary principles of bodies in a different manner. He first assumed two principles very different from one another; moisture and dryness, earth and water. The latter of these he divided into three species; namely, vitrifiable, inflammable, and mercurial earth. His vitrifiable earth was that which, taken alone, was not susceptible of any alteration, but possessed the property of forming a glass when mixed with a certain saline substance: he likewise ascribed to it the quality of rendering those bodies into the composition of which it entered, solid, and almost incapable of alteration. Inflammable earth was that which rendered all the bodies into which it entered capable of combustion: Beccher considered it as being likewise the cause of odour, colour, and volatility. Mercurial earth he considered as existing in mercury, arsenic, the muriatic acid, &c.; and the distinguishing characteristic which he assigned it, was to communicate an high degree of both gravity and volatility to those bodies of which it constituted part, though these two qualities seem directly opposite and inconsistent. Stahl adopted and illustrated the doctrine of Beccher. He considered inflammable earth as fire existing in a fixed state, and gave it the name of *phlogiston*. He found himself unable to demonstrate

demonstrate the existence of mercurial earth; and we have hitherto obtained no certain knowledge concerning that principle. Stahl paid great attention to combinations of earth and water, and still more to phlogiston, but has said scarce any thing of those which contain air; which Hales, nearly about the same time, discovered to act an important part in chemical phenomena.

From the days of Beccher and Stahl to the present time, chemists have made no change on the doctrine of the elements established by the philosophers of antiquity. They have followed Empedocles in acknowledging four principles, each of which they have considered as existing in two different states. 1. As free and insulated; and in this state have the atmosphere, large masses of water, fire in general, and the globe viewed as one whole, been considered: 2. As combined; and then the air, water, and earth obtained by the last analytical operations that can be performed on bodies, are the subjects of inquiry.

Such nearly were the opinions concerning the principles and elements of things that prevailed from the time of Beccher and Stahl, till the noble discoveries of Priestley and Lavoisier, concerning fire, air, and combustion, exploded these, to make way for others better founded. In fact, if immutability of properties, unity and simplicity, be the genuine characteristics of elements, and if this simplicity of character belong only to such bodies as we cannot reduce by decomposition, it is to be remarked, 1st, That of the four elements there are two, air and water, which art has at length found means to decompose and separate into several principles, 2^{dly}, That elementary earth is merely the

creature of fancy ; as there are a variety of earthy substances all equally simple and incapable of decomposition, as shall be shown in the last chapter of this part: *3dly*, That there are many natural bodies, as sulphur and the metals, which no art has yet been able to decompose, and which must therefore, in present state of our knowledge, be considered as simple substances.

From these general considerations, arising from facts which shall be more particularly related in the following chapters, and through the series of the work, it appears, that the true principles, or primary elements of natural bodies, escape the observation both of our senses and of those instruments which we employ to aid the imperfection of our senses: that many of those substances which have been called elements on account of their bulk, their influence on the phenomena of nature and their being found to exist in many of its productions, are far from being simple and unchangeable and that, in truth, none of the bodies with which we are acquainted, is a simple substance, though we usually ascribe this character to such as we have not hitherto been able to decompose. And these assertions entirely agree with the opinions of some ancient philosophers who considered not the elements as the simplest of substances, but believed them to be formed of principles infinitely more subtle and immutable.

What we advance concerning those substances which have for so many ages enjoyed the exclusive title of elements, but are now divested of that prerogative, does not hinder us from considering fire, water, earth, and air, forming the component principles of most natural bodies.

Let us dismiss this subject with an account of the terms which have been employed by some persons to distinguish bodies, according as their composition is more or less complex.

The combination of two elements forms a body that is called a *mixed*; the union of several mixeds constitutes a *compound*; two compounds make a *surcompound*; the combination of surcompounds gives a *decompound*; two or more of these united make a *surdecompound*. It would be difficult to give instances of these several kinds of compositions; we could indeed go no farther than to the surcompound. These distinctions are, therefore, merely fanciful, and can be of no real use in science. Macquer, to whom chemistry is much indebted for the present perspicuity of its doctrines, proposes to explode this barbarous and inaccurate nomenclature, and to adopt in its room, First, Second, Third, and Fourth Order. We might even pursue the same thought, so far as to adopt these names to distinguish principles according to the order of the analysis by which we obtain them.

C H A P. V.

Of Fire.

THOUGH we cannot agree to receive the word *element* in the same sense in which it was generally understood till the present time; though we cannot consider those four bodies, commonly called *the four elements*, as the first principles of all others, and the simplest productions of nature; yet we are willing to inquire into their nature before proceeding to others; because a knowledge of their properties is necessary to enable the reader to understand our account of the properties of other substances, and because they cannot be arranged under any of the divisions of natural history, being confined to no particular departments in nature, but extending equally through all.

None of the four elements displays greater activity or simplicity than *Fire*. The more ancient philosophers, who in this particular have been uniformly followed by their successors, gave this name to a substance which they supposed to be fluid, active, penetrating, consisting of particles actuated by a lively and incessant motion, and the first principle of all fluidity and motion. Whoever considers this subject, must readily perceive, that it was merely by conjecture they ascribed these properties to a particular elementary body: for though the existence of the other three elements have always been undeniably established, yet the existence

tence of this has never been demonstrated. There is **reason** to think, that in all languages, and among all **nations**, the first use of this word was to denote the **impression** which hot bodies make upon the skin; and **that** it is significant of the light which issues from bodies **in combustion**, as well as synonymous with the word **heat**. Many have considered it in this view, admitting **the existence** of fire only where heat is felt or **combustion** carried on. Chancellor Bacon was among the first **that** began to doubt the existence of fire as a particular **fluid**; and observed, that natural philosophers, in **defining** it, had always mistaken a property for a substance. **Boerhaave**, whose Treatise on Fire will be ever regarded as a masterpiece, was sensible of this difficulty; and **in order** to discover the properties of this pretended **element**, examined what effects it produces on those bodies **in which** it is believed to exist; so, like former philosophers, he has rather given the history of hot, luminous, rarefied, and burning bodies, than of fire. This difficulty must ever continue to perplex the philosopher. **The properties** of fire cannot but be intimately connected with those of the bodies on which it acts; we can form no idea of it as existing in a separate state. Notwithstanding the present advanced state of chemistry, the existence of this substance is still undetermined. Philosophers continue to believe in its existence, but are able to give a satisfactory explanation only of its effects. These difficulties have induced several chemists, among whom was the celebrated Macquer, to consider fire as being nothing more than light, and heat as a certain modification of bodies, produced by the motion and collision of their component particles. But this

opinion no longer prevails among those who cultivate chemistry. In order to enter into the several theories which have of late been advanced concerning fire, we must consider it in a more particular manner. To acquire an accurate knowledge of this matter, and comprehend that immense series of facts which at present constitute the body of the science of chemistry, we must make a methodical division of our subject, examine and discuss with pains its several parts and subdivisions, and consider in successive order, as so many distinct effects of fire,—light, heat, rarefaction, the changes produced on bodies by heat, and the particular qualities ascribed to fire in a state of combination, when it retains the name of Phlogiston, &c.

§ I. *Of Light.*

THE existence of light is not doubtful, like that of fire: both its existence and its properties are at present well known. This body, which is thought to come from the sun and the fixed stars, is the principle which enables the organs of sight to inform us of the properties of other bodies. Without it we should be in perpetual darkness, and our eyes would be useless. Being reflected in right lines from the surfaces of those bodies on which it falls, it strikes them in such a manner as to paint on the retina the images of those objects from which it is reflected. It has been found to collect its rays in a darkened chamber in such a manner as to render their properties more easy examination, by exhibiting them distinct figures which they illuminate.

The motion of light is so rapid, that it passes through the space of eighty thousand leagues * in a second of time, according to the most eminent astronomers. It moves in a rectilinear direction, and consists of rays, which, after issuing from the stars, separate and diverge in obedience to the impulse originally communicated to them. Such is their elasticity, that when they fall on a surface capable of reflecting them, the angle of their reflection is nearly equal to that of their incidence; as is seen in the study of catoptrics. When light passes near any body, it is more or less inflected towards that body; which inflection, by evincing its gravitation, shows it to be a distinct substance.

However great its subtlety and velocity, yet it does not move invariably in a right line. Such bodies as meet and obstruct its passage, cause it to deviate from its original direction. When passing obliquely out of a rare into a dense medium, it is refracted like any other solid body; but Newton † discovered its refrangibility to be directly contrary to that of other bodies. Other bodies recede from the perpendicular line whenever they pass into a denser medium; but light, on such an occasion, approaches nearer to the perpendicular. To explain the laws of the refraction of light is the province of dioptrics.

When light reaches the surface of the earth, it discovers to animals the presence of material bodies, and enables them to distinguish them into opaque, transparent,

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* Twenty-five of which make a degree; equal to 167,000 geog. miles.

H.

† We owe the first accurate account of these phenomena to D.

H.

rent, and coloured. Its presence is so necessary to render these properties perceptible, that in darkness bodies become totally undistinguishable. Difference of opacity, transparency, and colour in bodies, depends, therefore, on the manner in which they are affected by light or in which they affect this substance. A body is transparent when the rays of light pass easily through it, which depends no doubt on the form of its pores. Many transparent substances have great hardness and specific gravity, the particles of light which penetrate through them must therefore be extremely subtle. When the particles of light pass through those substances, they are refracted in the ratio of their density, if they be stones, salts, or vitreous substances: but transparent bodies of the combustible class reflect the particles of light in a different ratio. Thus, yellow amber has much greater refringent power than a saline crystal of equal density.

By examining the various refractions and reflections of light, the great Newton was at length enabled to decompose, or rather to dissect, this body, so far as to discover that the rays which compose a beam of light were each of a peculiar colour. Before him men's notions of the cause of colours were very obscure and indistinct. The refraction and reflection of each ray of light are determined by particular laws; and therefore when a stream of light is directed so as to fall on the angle of a triangular glass prism, and the prism is turned round on its axis; the rays which compose the stream of light being refracted according to different laws, are separated in passing through the glass, and if received on a plane white surface, form a long spectrum, con-

sisting of the seven following colours ; red, orange, yellow, green, blue, purple, and violet.

The surfaces of opaque variegated bodies produce the same effects as the prism on light. Such seems to be the cause of that diversity of colours which constitutes so considerable a part of the beauties of nature: When all the rays which fall upon any opaque body are reflected, without suffering any absorption or separation by that surface, they strike our eyes with all their lustre, and the colour produced is a white: But again, if the same rays fall on a surface by which they are all absorbed, the eye then beholds a deep shade; which being a direct contrast to the former, constitutes black, or rather absolute negation of colour. In short, as every beam of light consists of seven different coloured rays, of various degrees of refrangibility, what diversifies the colours of natural bodies is the various disposition of the particles of their surfaces ; some of which reflect one ray, absorbing all the rest, others another, and so on. Colour depends, therefore, on the nature of the surfaces of bodies, and transparency on the form of their pores ; and both are occasioned by the modifications produced on light, either by the superficies or the interior parts of the bodies on which it falls. A blue or red colour is produced by the decomposition of a beam of light, and the absorption of all its rays, excepting the blue or the red.

These are the chief properties of light, when considered in a free state, or as it issues from the sun and the fixed stars. But are we to examine it only in this free and insulated state? Is not this body, as well as all the rest with which we are acquainted, subject to

the laws of chemical attraction ? The phenomena of light are not confined to the modifications which it suffers from the surfaces of bodies. Substances exposed to its influence, by being immersed in its streams, often suffer an alteration and entire change of nature, without any other known cause ; and it is reasonable to think that such changes are produced by the operation of light which is enabled to effect them by being capable of chemical attraction. Art, indeed, has not yet been able to determine whether these alterations be occasioned by the decomposition of light, or by that of the bodies in contact with it, or by the mutual decomposition of both ; which last is highly probable : but they are too numerous and too striking to be passed over unnoticed. We shall here mention only a few of the most remarkable because our attention will be more particularly turned towards this object in the history of natural bodies.

Naturalists have long observed the influence of light on vegetation. Those engaged in the cultivation of plants first observed, that such as grow in the shade are of a paler colour. This phenomenon has received the name of *ætiolation* ; and the plants on which it takes place are said to be *ætiolated*. Herbs growing under stones are white, soft, aqueous, and insipid. Gardeners take advantage of this circumstance to supply our tables with white and tender herbs and pulse ; for they bind their leaves so closely together, that the exterior defend the interior from the contact of the light. The colour of herbs is pale or deep in proportion as they are less or more exposed to the rays of the sun ; and in consequence of this, the nations of the east obtain from the wood, bark, or roots of trees, many of the most valuable

ble colouring stuffs, both for permanency and lustre, which all the ingenuity of European dyers has never been able to imitate.

Colour is not the only property that vegetables derive from the influence of light. From the same source they acquire taste, smell, and combustibility. Thus light contributes to the ripening of fruits and seeds; and under the torrid climate of America, vegetables in general are highly odorous, sapid, and resinous, &c. Lastly, light exerts so powerful an energy on the organization of vegetables, that when the rays of the sun fall upon them, their leaves pour from their superior pores copious streams of vital air; but when hid from the influence of that planet, they exhale a deleterious mephitic, or rather a real acid, of the same nature with that which is extracted from chalk. This important discovery was first made by Dr. Priestley. M. Ingenhoufze has prosecuted it much farther; and from the experiments and observations of both, it appears how powerful the influence of light is on vegetation. In a great number of chemical operations, light is found to act with the same energy as in these more general instances. There is not one substance in nature, that, if put into a close glass vessel, and exposed to the rays of the sun, will not suffer some alteration from their influence. These alterations are most remarkable in mineral acids, oxides, or metallic calces, vegetable powder, and volatile animal oils. Not a single metallic oxide, though more especially that of mercury, but suffers a change of colour, assuming generally a deeper shade from being exposed to the rays of the sun. Painters' colours which are kept by merchants in glass bottles,

bles,

tles, afford a good instance of this. Mineral acids exposed to the sun become fuming, higher coloured, and more volatile; metallic salts become black; animal oils assume a brown dusky colour. All these changes merit the most careful attention of chemists; they afford vast scope to research, and have not hitherto been observed with sufficient care. Scheele was the first who described any of them. M. Berthollet has also turned his views to this object; and we shall afterwards see that he has determined accurately what passes in many of these alterations.

§ II. *Of Heat.*

To examine the properties of heat is a much more difficult task than to examine those of light. Bodies when heated acquire no additional gravity; which might serve to prove that heat is a distinct substance. Bacon, and many other great men, have thought heat to be only a certain modification of which bodies are susceptible. It is certain that natural philosophers, as well as other men, have always considered its presence as a sure indication of the presence of fire; have sometimes confounded it with that element; and sometimes considered heat as one of the distinguishing properties of fire.

Its leading properties are, to penetrate through all bodies; to diffuse itself equally, and to tend to an equilibrium; to dilate all substances into which it insinuates itself, causing them to pass from a solid to a fluid state, and from this to assume the form of elastic fluids.

Heat is usually communicated to bodies in one or another of these three ways; by contact, by motion, or
by

by combination. Every person must have observed, that when two fluids different in temperature, the one sensibly warm, and the other sensibly cold, are mingled together, the former loses part of its heat, which is communicated to the second, so that the temperatures of both become the same. It is equally well known, that when two solids, the one warm, the other cold, approach each other, the latter robs the former of part of its heat, and the temperatures become equal. As to the calling forth of heat by motion; the friction of any two solid substances, such as two hard stones, two pieces of wood, ivory, or metal, produces a heat which often rises to inflammation. The production of heat by combination is no less undeniable. The union of concentrated acids with water, quicklime, pure alkalis, or metals, is productive of a strong heat: the combination of certain fluids, such as oil and spirit of nitre, is even so powerful this way as to cause inflammation.

The laws of the communication of heat were considered as analogous to those of motion, till the labours of Messrs Black of Edinburgh, Wilcke of Stockholm, Irvine of Glasgow, Crawford and Kirwan of London, and Lavoisier of Paris, gave us new and more accurate ideas on the subject. The researches of these philosophers have shown, that nothing was less known, or involved in greater difficulties, than the progress and communication of heat among bodies unequally heated. Their experiments, though highly ingenious, are not yet sufficiently numerous. They themselves do not presume to consider their observations as of sufficient weight to form an elementary part in the science of chemistry: But it is highly probable that these will lead

to the establishment of a general theory, which may be applied to all the phenomena of chemistry; in every one of which heat acts a part, by either its absorption or disengagement.

Even the nicest and most accurate observations have been hitherto insufficient to afford us any determinate ideas of the nature of heat; and both chemists and natural philosophers are still divided in their opinions on this subject. Part follow Bacon of Verulam, in considering heat to be nothing more than a modification which all natural bodies are susceptible; which has no separate existence, but consists in the oscillation of the minute particles of bodies. This was Macquer's opinion. The philosophers who maintain it, support it on the following facts. Heat accompanies all the phenomena of motion, and appears subject to the same laws: It is increased with the increase of motion, and diminished by its diminution. Excepting its communication or passage from one body into another, which it follows laws different from those of motion, in all other respects there is a striking analogy between the two; and when this cause acts with less force, it entirely ceases to act, heat is instantly diminished, and is soon totally lost. To explain this hypothesis, the philosophers by whom it is maintained observe, that even bodies of the greatest density are full of small cavities or pores, the sum of which if they were taken together would perhaps occupy a larger space than the solid matter of the body that contains them. These void spaces afford room for the particles to move one against another in a continual oscillation. The oscillations are not observed, because both the particles and pores are

so subtle and minute as to elude our senses. Lastly, The philosophers who regard heat as an internal motion, urge that no experiment has hitherto demonstrated its existence in a separate state, and that it makes no addition to the gravity of bodies, &c.

On the contrary, many other philosophers, and some modern chemists, are of opinion, that heat is a particular fluid, diffused through all nature, of which every body contains more or less. They distinguish this fluid as existing in two different states,—in combination, and at liberty. In the former state, it neither affects our senses nor the thermometer, but remains quiescent in those bodies of which it constitutes a principle; it is then more or less in a state of confinement. In the decomposition of the bodies it is often disengaged, and escapes into a state of liberty: it now becomes capable of acting on bodies exposed to its influence; and its force is measurable by a graduated thermometer. As all bodies that pass from a solid to a fluid state, and thence into a vaporous form, excite cold in the surrounding atmosphere, they suspect that such bodies absorb a great quantity of heat; and when fluids, by assuming a concrete form, generate heat, they think that heat is then disengaged from those substances, and passes from a state of combination into a state of liberty.

Scheele, as well as Bergman, being persuaded that heat is a distinct substance, has examined with great attention all the phenomena which it displays as a chemical agent susceptible of combination. He has even thought himself warranted by his experiments to conclude, that it is a combination of vital air, which he calls *empyreal fire*, and fixed fire or phlogiston, and
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differs from light only in the relative quantity of the last principle. But however ingenious and accurate his experiments, the inductions which he has drawn from them concerning the nature and principles of heat, do not appear to be naturally deducible from the facts; and we cannot consider his analysis of heat as fully demonstrated to be just. Some philosophers are of opinion, that light and heat are the same substance, only existing in different states. This substance becomes light, when its particles being collected together, and possessing all their attractive force, are violently darted to a distance: it assumes the character of heat, when the same particles exist in a state of division, move gently, and tend towards an equilibrium. Heat may be converted into light, and light again into heat. It must be acknowledged, however, that light often produces effects very different from those of heat; as on the nitric acid, the oxygenated muriatic acid, the calces or oxides of metals, and the leaves of vegetables dipped in water; all which bodies afford vital air or oxygenous gas when exposed to the rays of the sun, which can be obtained from scarce any of them by the operation of heat. Thus the artificial light of our fires passing through vessels, changes the nature of the products which it disengages. Lastly, Messrs Lavoisier and De la Place seem to think both these opinions true: they consider heat as a distinct substance, which by its presence in natural bodies occasions an oscillation of their component particles.

But though the nature of heat be not certainly known, the phenomena to which it gives rise in chemical combinations and decompositions are not the less certain

certain on that account, and are worthy of careful observation. It appears from a vast variety of facts, that **whether** a body or a modification, it is of itself liable to **no** alteration, and is never lost; and the consideration of this has induced Messrs Lavoisier and De la Place to **form** an axiom or general principle concerning its appearance or disappearance. As that axiom is of the **highest** consequence, we shall insert it here.

“ If in a combination, or in any change of state **whatsoever**, there be a diminution of free heat, the **whole** of that heat will again appear when the substances are restored to their former state; and on the contrary, if in any combination or change of state there be **an** increase of free heat, this additional heat will disappear when the substances return to their original state.”

They generalize this principle still farther, so as to **make** it extend to all the phenomena of heat; and they then express it in the following terms. “ All the **variations** of heat, whether real or apparent, that any **system** of bodies can suffer, are reproduced in an **inverse** order when the system returns to its original state.”

In order to measure the quantity of heat that is absorbed or disengaged in the various phenomena of chemistry, which appears from what has been said, to be **an** object of the highest importance; modern philosophers have endeavoured to find means for correcting the observations of the thermometer, and extending its scale. M. Wilcke proposed to estimate the heats of bodies by observing what quantities of snow they could melt in a given time. Messrs Lavoisier and De la Place

have contrived a method which is more certain and more easily practicable; reducing substances that produce heat by their combination, as well as the vessels in which they are contained, to the temperature of 32° Fahrenheit they then put them into a vessel laid round with ice and as the interior surface of the ice cannot be melted but by the heat which is disengaged while the substances are entering into combination, the quantity of the heat thus disengaged may be measured by the quantity of the water obtained by the melting of the ice, which must be carefully collected*. By this process they have been able to estimate the specific heats of various bodies, to measure the quantity of heat absorbed in various combinations, and even to determine how much is disengaged in combination and respiration. We are obliged to refer our readers to the work of those learned academicians themselves, for an account of this ingenious instrument, and the manner in which it is to be applied to the various purposes for which it is adapted; as the detail of particulars necessary to explain it would be inconsistent with that brevity which we mean to follow through the course of this work †.

Here let us consider more particularly the resemblance that appears in some instances between light and heat, as well as those peculiarities by which they are distinguished from each other in the operations
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* We understand from the Philosophical Transactions, that in some attempts made by an ingenious Englishman, it was found that even this method may be fallacious.—H.

† See a Memoir on Heat, read before the Royal Academy of Sciences on the 28th of June 1783, by Messrs Lavoisier and De la Place of that Academy.—F.

both of nature and art. Though the light of the sun's rays warm those bodies on which it falls; yet we must not conclude from this circumstance that light and heat are the same; there are a great many instances in which light is totally destitute of heat, and others again in which heat is not accompanied with light; and a number of philosophers therefore consider them as essentially different. In fact, phosphori, diamonds, putrid wood, animal substances in a state of putrefaction, luminous insects and worms, as well as the rays of the moon, concentrated on metallic mirrors or lenses, afford a strong sparkling light, but no sensible heat; and all the bodies in nature may be strongly heated without becoming luminous.

The rays of the sun appear to produce heat merely by their impulse on the bodies on which they fall, or by the friction which they suffer from those through which they pass. Red, and more particularly black opaque bodies, are sooner heated than white, bright surfaces; doubtless because they refract the rays more powerfully, and perhaps even because light enters into combination with those high-coloured substances, while white surfaces do not absorb, but reflect the rays which fall upon them.

With regard to the production of light by a strong continued heat, as in the combustion of oils, wood, or grease, and the ignition of metals and stones; this may also be accounted for without allowing the identity of light and heat. When combustible bodies are strongly ignited, they at length produce flame; which has the same effects as the rays of the sun, and supplies their absence. But this light which is produced by inflammation,

mation, may have before subsisted either in the combustible body or in the air, the presence of which is necessary for its production: and this fact, therefore affords no proof that heat may be changed into light. The ignition of incombustible bodies, such as stones, in which light cannot subsist in a combined state, not at least in the same manner as in combustible bodies, has been very ingeniously explained by Macquer. In his opinion it depends on the strength of the vibration communicated to the particles of those bodies by the impulse of heat. Those vibrations dispose the particles in such a manner, that their facets, acting like so many little mirrors, reflect upon our eyes the rays of light, which exist in the air by night as well as by day; for we are involved in darkness during the night, for no other reason but because these are not then so directed as to fall upon our organs of sight.

Such were the notions of Macquer and of many other philosophers. But a very numerous series of accurate facts concerning the differences of heat in bodies, the capacity of bodies to absorb it, and the elective attractions to which it is subject, render the existence of heat as a distinct body much more probable than ever. It is thought to be often a principle in compound bodies, and the lightest of all the substances in nature; and this last property is considered as the reason why we cannot determine its existence by its weight. Heat is distinguished into two kinds, or rather as existing in two different states; in the one, it is intimately combined with other principles, and is denominated *latent heat*, or the *caloric* principle, because it is not perceptible to the senses; in the other, it is only diffused without combination

bination. This last kind of heat may be expelled by pressure: thus, when a bar of iron is struck, the stroke compresses its particles and causes the heat to issue out, in the same manner as water issues from a wet sponge when it is pressed together with the hand. Combined heat cannot be separated from the bodies of which it forms a part, but by means of new chemical combinations. All solid bodies that contain any portion of these two kinds of heat, are capable of receiving more of both. When you add a quantity of the second species to any body, its first effect is to enlarge the pores that separate its component particles, by which means it softens a solid; next, as it gradually accumulates, it produces fusion or liquefaction; and as the quantity of heat continues to increase, elastic fluidity follows: But we shall treat of these phenomena in the two following sections.

§ III. *Of Rarefaction.*

RAREFACTION is the most remarkable of all the effects which philosophers ascribe to fire, and is constantly produced by heat. We have already taken notice that the chief effect of heat is to diminish the specific gravity of bodies, by extending their bulk, without adding any thing to their absolute weight. This rarefaction shows, that some new substance is introduced into the cavities of the rarefied body. This substance, which is no other than heat, acts in proportion to the interstices which separate the component particles of the body. Bodies when rarefied by heat gain no additional weight, and have their specific gravity diminished.

ed ; because rarefaction consists simply in the separation of the parts of the warm body, its pores being enlarged so that there is more vacuity and less solid matter than before in a given space. This separation of parts is effected by heat, which is to us, in point of weight, mere non-entity.

When we consider, that the particles of bodies rarified by heat, suffer an internal motion, which tends to divide them from one another; and that cold, on the contrary compresses and condenses them; we are led to consider heat as a force opposed to the mutual gravitation of those particles, which weakens their particular attraction: For it is to be observed, that there are three modifications of the Newtonian attraction which ought to be carefully distinguished from one another. The first state of attraction is that which operates with a primary impulse to retain the planets in their orbits, preventing them from approaching the sun, upon whom they would soon fall were it not for the centrifugal force which they have received from their primary impulse; this may be called *planetary attraction*, to distinguish it from the other two. The second state or modification of attraction is that which causes bodies projected into the atmosphere of our globe to tend towards the centre: this is *terrestrial gravitation*. The third modification of this general force is that which causes the several parts of any body to tend to their common centre: such as a stone or any other consistant body: this force produces aggregation, and in its various degrees is the cause of specific gravity: It is the last species that heat diminishes and tends to annihilate, and by acting in opposition to this force, it produces
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infinite variety of effects in combination, decomposition, vegetation, animalization, &c.

Boerhaave, who has examined the effects of fire rather as a philosopher than a chemist, has established three general laws concerning rarefaction, which we shall examine.

FIRST LAW.



All bodies are dilated by heat.

THOUGH it be a general truth, that heat dilates and rarefies almost all natural bodies, yet we may make a few remarks on this phenomenon. First, all mineral substances without exception are dilated and rarefied in the direct proportion of the strength of the heat to which they are exposed. This rarefaction may even be carried so far as to destroy the aggregation of many among them ; but vegetable and animal substances afford some exceptions to this law. A gentle heat indeed dilates their fibres, divides them, and thus diminishes their consistency ; but a sudden strong heat causes parchment, membranes, and tendons, to shrink and contract their bulk ; which seems to be occasioned by the irritability, or more properly the contractive force, of animal fibres, on which heat appears to act as a stimulus, till their organization be destroyed.

SECOND LAW.

All the dimensions of bodies rarefied by heat, are dilated.

A BAR of iron ignited becomes both longer and thicker. Philosophers have contrived several inf

which are still but very imperfectly known, it is of importance to know, 1. That bodies always produce cold when they pass from a solid to a fluid state ; as for instance, salts when dissolved in water, evaporating æther, &c. 2. That fluids capable of assuming a concrete form, generate heat as they become solid : thus water, which freezes when put into a freezing mixture never affords so high a degree of cold as spirit of wine put into the same mixture. It may be understood from what has been said, that when a solid body becomes liquid, it absorbs an additional quantity of heat ; and when a liquid body becomes solid, part of the heat which it contained is disengaged.

§ IV. *Of the Pblogiston of Stahl.*

BECCHER, struck with that property of certain bodies which enables them to produce fire, that is to say, light and heat, in consequence of continued motion, or by coming into contact with other bodies in a state of ignition, imagined it to depend on a distinct principle, to which he gave the name of *inflammabilem earth*. Stahl, whose attention was strongly engaged by this doctrine, understood this principle to be pure fire, or the matter of fire fixed in combustible bodies. To this element, existing in such a state of combination, he gave the name of *pblogiston*, or the *inflammable principle*, to distinguish it from fire in free or active state. Its properties, when combined are totally different from those which it displays when at liberty : it then gives neither heat nor light, though in the latter state, these are its constant attendants.

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But, when freed from confinement, it constantly regains its characteristic properties, and its presence is indicated by both heat and light. Such was the sublime and simple idea of Stahl concerning the nature of combustible bodies. It is indeed natural to think, that those substances which, when strongly heated or forcibly struck, become inflamed, and continue to burn till they be consumed, owe this property to their latent fire; and that the combustion of such bodies is nothing but the disengagement of the fire, and its passing to a state of liberty. According to Stahl, therefore, all combustible bodies contained fire in a fixed or combined state, on which principle their inflammability depended. He also considered this principle as being perfectly the same in all the substances into which it entered, whatever their nature, or however different they might be from one another. The combustibility of any body appeared to him a sufficient proof that it contained a quantity of phlogiston. Thus, in his opinion, sulphur, charcoal, metals, oils, and phosphorus, owed all their properties to phlogiston; and their differences in point of form, colour, consistency, gravity, &c. might depend, he thought, on the variety of the principles to which the phlogiston was united; for the phlogiston itself was always the same, and could suffer no variation but by being dismissed from a combined into a free state.

In order to distinguish the properties of phlogiston or fixed fire, Stahl instituted a comparison between bodies into the composition of which it enters, and others that seem destitute of it. He observed the former to possess in general, colour, smell, fusibility, vola-

dies, as he hoped, from the examination of their nature, to determine the character of phlogiston, that he seems to have forgotten that air is essentially necessary to combustion. In consequence of this, he has overlooked this objection against his theory, which was not indeed urged against him by any contemporary chemist. If combustion be nothing but the disengagement of phlogiston, it is plainly an act of decomposition, in which the combustible body loses one of its principles. But how is it possible for a body, after having lost one of its component principles, to possess considerably more absolute weight than before? An hundred lib weight of lead affords an hundred and ten of minium the weight of the sulphuric acid obtained by the combustion of sulphur, is greater than that of the sulphur from which it was obtained: and, in the same manner we learn from the fine discovery of M. Lavoisier, that eighteen ounces of pure water are obtained by burning sixteen ounces of spirit of wine *.

The strength of this objection, together with the difficulty that is found in every attempt to demonstrate the existence of phlogiston, have induced some modern chemists to deny that there is such a substance in nature. But they must not be implicitly listened to; even the numerous train of experiments which have been of late made on combustible bodies and combustion, have not fully demonstrated that there is no such principle as fixed fire in material bodies: its existence seems to be allowed, while its name is changed; and instead of the phlogistic, it is called the *caloric*, principle. It is divested

* Meeting of the Royal Academy of Sciences on the 4th of September 1784.—F.

vested, however, of the property of producing combustion; and though it be acknowledged to exist in inflammable bodies, it is not considered as the cause of their inflammability.

Since chemists began to inquire how far the presence of air is necessary to combustion, they have made several important discoveries; the chief of which is, that a certain quantity of atmospheric air is always absorbed by burning bodies, and that it is the acquisition of this air, which becomes fixed or combined, that augments the absolute gravity of metals, sulphur, phosphorus, inflammable gas, and spirit of wine, when exposed to combustion. As this increase of gravity has been likewise found to correspond precisely with the weight of the air absorbed, several chemists, at the head of whom may be reckoned Messrs Lavoisier and Berquet, were led to adopt a new theory, founded solely on this absorption of air, in which they entirely rejected phlogiston. This theory was directly opposite to Stahl's, and consisted of the four following principles:

1. Stahl's phlogisticated bodies are, according to this doctrine, substances which have a strong tendency to combine with air; for on this tendency the combustibility of bodies entirely depends.
2. All the phenomena which Stahl ascribed to the disengagement of phlogiston are produced by combinations with pure air: such are combustion, calcination, respiration, and the formation of the sulphuric and phosphoric acids, by the combustion of sulphur and phosphorus.
3. On the other hand, according to the pneumatic theory, all those phenomena in which the doctrine of

Stahl represents the phlogistic principle as entering into new combinations, are produced by the disengagement of air. Such are the reduction of metals, effected by the mutual action of metallic calces and charcoal; the decomposition of acids by combustible bodies, and particularly the decomposition of the sulphuric and nitrous acids by iron, charcoal, &c.

4. This theory views all those bodies which Stahl thought to be compounds, with phlogiston for one of their principles, as simple substances, having so strong an affinity with pure air, that they attempt to enter into combination with it whenever they are exposed to its contact. Combustion is, therefore, nothing but the combination of air with the combustible body; and all operations in which bodies are thought to regain the phlogiston, are merely the disengagement of pure air or its passing out of one body into another.

This opinion, which was adopted by M. Bucquet in his latter courses of lectures, explains indeed most of the phenomena of combustion, calcination, and the reduction of metallic calces; but it does not entirely explain why flame is seen to proceed from combustible bodies in a state of ignition; nor does it account for the rapid motion produced in inflammation; and the other changes which attend this phenomenon. Macquer, after carefully examining how far the modern discoveries could affect the received theories, was of opinion that they were insufficient to explode the theory of Stahl and has therefore combined the pneumatic with the phlogistic doctrine, by representing phlogiston as light in a state of fixation. After showing that pure light such as that which the sun diffuses over our globe, may

be considered as the substance of fire, and, by being fixed in bodies, may actually constitute the phlogiston of Stahl; he next gives it as his opinion, that in every act of combustion, pure air disengages the light or phlogiston of combustible bodies, and possesses itself of its place; and that the calcination of metals may therefore be regarded as the precipitation of air, and the disengagement of light. Again, when phlogiston is restored to the calces of metals by reduction, light, in its turn, disengages or separates the air which was fixed in those substances, and by that means causes them to resume the character of metals. Macquer also thought; and it was necessary to his theory, formed with a view to reconcile Stahl's with the modern doctrine; that phlogiston may combine with bodies even in close vessels, since light is well known to penetrate through glass, and even through metal and earthen vessels, when these are made red-hot. Scheele has proposed a different theory, which has also been adopted by some northern chemists. He considered fire, heat, and light, as compounds of vital air with phlogiston; and thought that light in passing through vessels, suffered decomposition, the phlogiston in the reduction of metallic calces or oxides being communicated to the calx, while the vital air was disengaged. But this ingenious theory, by which Scheele accounted for the effects of solar light, and of the various modifications of heat on a great many chemical phenomena, affords no explanation of the increase of the weight of metals, sulphur, and phosphorus, &c. after combustion.

M. Lavoisier, whose experiments have contributed so highly to the advancement of chemistry, and whose o-

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pinion must therefore have considerable weight, has proposed a new theory that has been adopted by most French chemists, and appears to me to afford a happier explanation of the phenomena of Nature than any other. He thinks that light, heat, and all the other remarkable phenomena of combustion, depend rather on a certain action of the air than on the peculiar nature of combustible bodies; that the flame which then arises is occasioned by the disengagement of the light which was combined with the pure air, not of that which existed in the combustible body. He ascribes to pure air that decomposition which, according to Stahl and Macquer, takes place on the inflammable substance. Pure air he considers as a compound of the substance of fire and another principle which shall be afterwards described; and the fixed fire, the disengagement of which is the principal act on such occasions, is, in his opinion, separated from the pure air, not from the combustible body. We cannot enter more particularly into this ingenious system in this place. In the history of air, in the following chapter, it will come more properly under our examination. At present we shall content ourselves with observing, that the fire or heat, which M. Lavoisier allows as a principle of pure air, and the disengagement of which he takes to be the cause of the sparkling flame and vivid heat which accompany the rapid combustion produced by that air, act nearly the same part with Stahl's phlogiston, or Macquer's fixed light; and that chemists seem to have universally agreed concerning the existence of this principle, the only difference among them being, that one party believe it to exist in combustible bodies, and to be the cause

use of inflammability; while another consider it as a principle of air, and ascribe inflammation to a different use. In the following chapters, we shall explain the reasons which induce us to prefer the latter of these opinions.

V. The Effects of Heat on Bodies considered Chemically.

In the third subdivision of this chapter, it was shown that one of the chief effects of heat is to rarefy bodies, increase their bulk, and diminish their specific gravity, by separating their particles, and enlarging their spaces. Such was the simple physical or mechanical idea which we gave when speaking of rarefaction in general; but when we attend more carefully to this primary act of heat, we shall find that it produces several other important effects.

The first and most striking effect of heat, is its diminishing the aggregation of bodies, by separating their particles. As the force of aggregation, and that of the reaction of composition, are always in the inverse ratio of one another, as has been shown in the third chapter; it will be readily understood that heat, in destroying aggregation, must be singularly favourable to combination. This has caused fire to be considered as the principal chemical agent, and has even induced chemists to assume the title of *philosophers by fire*. It will afterwards appear, however, that they make much less use of it at present than they formerly did.

The action of heat, when considered in this point of view, as tending to destroy aggregation, and favouring combination, appears liable to four different modifications.

tions, according to the nature of the bodies on which it exerts its energy.

1. There are some bodies on which it produces no alteration, nor any effect but dilatation. Substances of this nature are unalterable and *apyrrous*. Thus diamond, however long exposed to the utmost violent fire suffers no alteration: it loses neither its hardness nor transparency, and appears, after this assay, with its former density and beauty. But there are very few substances so little alterable as rock-crystal.

2dly, Heat entirely destroys the aggregation of bodies, causing them to pass from a solid to a fluid. This phenomenon is named *fusion*; the bodies on which it is produced, are called *fusible*. There are various degrees of fusibility, from that of platina, which is extremely difficult to melt, to that of mercury which remains always in a fluid state. When this fusibility is carried to an excessive degree, it becomes volatilization. A body becomes volatile, or diffuses itself through the atmosphere, when it is caused to pass, by a strong action, from the liquid state to that of an elastic fluid. It is then dissipated by heat, and elevated in the atmosphere, where it remains suspended till cold reduces to it part of its density and specific gravity. Bodies which may be reduced to this state are named *volatile*; those incapable of it are, by way of opposition, called *fixed*. There are many degrees between fixity and volatility. It even seems impossible to suppose any body absolutely fixed. Perhaps the only reason why any appear so, is, because we cannot apply to them a degree of heat sufficiently intense. We may make the same remark on infusibility; it is never absolute. The

son why rock crystal appears infusible, is, because we cannot apply to it the proper degree of heat. When we speak, therefore, of the infusibility or the fixity of certain substances, we are to be understood as speaking only in reference to the heat to which it is in our power to subject them.

This essential volatility is to be carefully distinguished from that which is merely apparent, and takes place only in consequence of the communication of motion by a current of flame or vapours: Thus, for instance, zinc, in a state of calcination, is carried up by the flame that is raised during its combustion.

3dly, When heat acts on bodies consisting of two principles, one volatile, the other fixed, it generally separates them by volatilizing the former. Such bodies are thus decomposed, but without suffering any alteration; for by reuniting their principles, we can reproduce them with all their original properties. This separation of principles is a true or simple analysis. Fire applied to bodies consisting of two substances, between which there is a wide difference in respect of volatility, reduces the volatile principle to vapours, but leaves the fixed uninjured. But in order that this true analysis may take place, it is requisite that both the volatile and the fixed principle of the compound be unalterable by the degree of heat applied to them; or that they be exposed only to such a degree of heat as they can bear without losing any of their properties. The volatilized substance having then undergone no greater alteration than the fixed, they may be reunited as to form the same compound which they constituted before their separation. When this may be effected,

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ted, the analysis is true or simple. As bodies do not generally consist of two principles, one of which is volatile the other fixed, and as it is often extremely difficult, and sometimes even impossible, to apply to compounds of this kind precisely that degree of heat which will volatilize the one without alteration, and leave the other uninjured; it may be naturally inferred, that the number of the bodies on which heat acts in this manner must be very inconsiderable. For this reason chemists have now much less frequently recourse to the operation of fire than formerly. The substances on which heat produces this effect are *decomposable without alteration*. Some mineral substances, such as crystallized salts and solutions of neutral salts, come under this class.

4^{thly}, When the body exposed to the action of fire consists of several volatile and several fixed principles, the volatilized principles enter into mutual union; the fixed are also combined with one another: and such is the result of this decomposition, that though the products be reunited with the residues, the original compound will not be produced. This is therefore a false or complicated analysis. The bodies on which heat acts in this manner are *decomposable with alteration*.

Most natural substances belong to this class. They are too complex in their composition, and consist of too many principles, to be decomposed without suffering alteration. As the force of the affinity of composition acts upon all bodies, and is even promoted by heat, when any of the principles of a compound is volatilized by the action of fire, they react upon each other, unite, and form a new order of combination different

different from that in which they before subsisted : the same thing takes place on the fixed principles of the body. Thus, when a piece of wood, bark, or any other vegetable substance, is exposed to the action of fire ; the water, the salts, and the oil, unite together, and constitute an acid, elastic fluids, and a brown oil, &c. which did not exist in the wood in that form. The action of heat, therefore, produces a total alteration on such substances : the phenomena which attend it indicate a false or complicated analysis, the results of which might lead chemists into mistakes were they not aware of the uncertainty with which it is attended. It is certain that art can never reproduce wood or bark, by mixing together the phlegm, oil, acid, and charcoal obtained in this analysis, and that the principles which it affords have suffered great alterations. Unluckily the bodies susceptible of these alterations are the more numerous class. Under it all animal and vegetable, and most mineral, substances are to be ranked. But the modern discoveries will enable us to determine the true nature of the principles of such substances, by examining such of them as are disengaged.

Hitherto we have spoken only of the effects of such a strong heat as is usually employed in the operations of art : But a gentle and continued heat, such as that which is exerted in the operations of nature, gives rise to a number of important phenomena, which are highly worthy of the chemist's attention. The vibration and oscillation of the particles of solid bodies which its impulse occasions, and the agitation and rarefaction of fluids arising from the same cause, produce a continued internal motion which gradually changes the form, the

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dimensions, and the contexture, of the former; and produces a sensible alteration on the consistency, the colour, the taste, and, in a word, on the intimate nature, of the latter. Such is the general idea which we have reason to form concerning the existence and power of all the chemical phenomena of natural bodies; concerning the spontaneous decomposition and recombination of minerals; concerning the crystallization, the solution, the formation of salts, the vitrification, the metallization, the vitriolization, and the mineralization, which are carried on in the bowels of the earth. To this powerful agent we must likewise have recourse, when we attempt to form an idea of the alterations to which animal and vegetable substances are liable; of the motion of the sap in plants, and the mild fermentation which conducts them to maturity; of the formation of oils, the spiritus rector, mucilages, and the colouring principle; or of the composition, the decomposition, the reciprocal changes, and the putrefaction of animal humours. All these important phenomena depend, more or less, on chemical operations; and that heat which is diffused over the globe is the great principle by which they are produced. It is at present enough for us to have taken a general view of this great cause of motion, life, and death. We have here sketched the outlines of the picture; in what follows we shall endeavour to fill them up with a nice and faithful hand.

As the various effects of heat depend all on its power of separating the particles of bodies, let us farther consider this first effect, and attempt to estimate its influence.

Water in the state of ice is softened by a certain de-

gree of heat, melted, and reduced to fluidity by a greater, and by a still greater degree reduced to vapour, or an elastic fluid : so that water in a state of vapour may be said to contain three sums of heat ;—that which constitutes ice of a certain density ; that which reduces ice to the state of a liquid, rarefied to a certain degree ; and, lastly, that which rarefies the liquid to an elastic fluid.

When we attempt to apply this theory to all natural bodies, they appear to be all capable of passing through these several states if exposed to a sufficient heat. The only difference among them, in point of this property, is, that some may be reduced by a less degree of heat while others require a greater. It is only for want of sufficient heat that we cannot reduce rock-crystal to a liquid or a vaporous state : nor is it more difficult to conceive the possibility of this event, than to conceive an habitually elastic fluid, such as air, acquiring an extreme solidity, as happens to this very substance in various combinations.

From these principles, it is easy to explain the formation of the elastic fluids which are disengaged in many of the operations of nature and art. It uniformly happens, whenever a body receives and absorbs a sufficient quantity of heat to cause it to pass into that state of fluidity which constitutes an aëriform fluid ; and therefore all fluids that possess this property owe it to heat. But it is also requisite, that the pressure of surrounding bodies, especially the pressure of air, do not oppose this extreme dilatation ; or that the dilatation be so great as to overcome the resistance which it meets with in the gravity of the air. Hence a body,

whether nearer to or more distant from the state of elastic fluidity, may be easily reduced to this state by relieving it of the pressure of the atmosphere, as elastic fluidity always takes place *in vacuo*. Hence evaporation is most quick and copious on the tops of lofty mountains. And hence too it becomes necessary to mention precisely, in a detail of experiments, with what degree of pressure any body was reduced to an elastic fluid, or at least what pressure it can bear in that state: for it is also to be observed, that all the bodies which can, with more or less ease, be reduced to the state of vaporous or elastic fluidity, do not maintain themselves in that state with equal constancy; nay, such are the differences among them in this respect, that they have been divided into *permanent* and *non-permanent*. The former remain long in the state of elastic fluidity; nor do they pass from it, till by some new combination they are deprived of the substantial heat by which they were maintained in that state. The latter, which may be denominated vapours, lose their elastic fluidity by degrees of pressure or cold which may be easily estimated, and readily communicate to surrounding bodies that portion of heat which constitutes them æriform fluids. Of this kind are water, alcohol or spirit of wine, and æther; these three fluids are reduced into vapours, and remain in that state when the barometer stands at 28 inches,—water at 212° Fahrenheit, spirit of wine at 180°, 30', and æther at 104°, &c.—It appears then, 1st, That the state of elastic fluidity is a mode of the existence of bodies occasioned by the combination of heat with their other principles: 2^{dly}, That every elastic fluid is a compound, consisting of a
base

case of more or less solidity, and the matter of heat: 3dly, That the base of every elastic fluid requires a certain degree of heat to reduce it to vapour or elastic fluidity; and that it is doubtless in consequence of their possessing these properties, that elastic fluids differ in gravity, elasticity, &c.

M. Lavoisier has explained this theory with great perspicuity, in a memoir printed among the Memoirs of the Academy of Sciences for 1777.

Although we have distinguished elastic fluids into permanent and non-permanent, yet it is to be observed, that this distinction exists not in nature. It is relative to the moderate heat and pressure of the atmosphere to which we are exposed in the climates in which we live, and over many parts of the globe; and if the cold and pressure were more considerable, even the fluids which we at present consider as the most permanent, would soon cease to be so; and, on the contrary, æther and spirit of wine would become permanent elastic fluids at a certain height in the atmosphere, or in the warm temperature of the equatorial climates.

As the substance of heat, which contributes to the formation of elastic fluids, exists in them in a combination or latent state, and becomes not perceptible to our senses till those bodies lose their fluidity by entering into combination with other substances; we have therefore sought for an expression proper to denote heat in this state, and have adopted the word *caloric* for this purpose; because in this state heat may be actually considered as having lost its original character, which recovers not till it be restored to a state of liberty. Besides, by affixing to it this denomination, we avoid the

the circumlocutions of the substance or matter of heat, or latent heat, which have been hitherto applied to it. Cooling, or the passing of heat into the state of caloric, and ignition, or the passing of caloric into the state of heat, depend both on the general law above laid down, that when bodies become more dense, part of their heat is exhaled. Thus, whenever a gas or aëriiform fluid is combined so as to become a liquid or a solid, it loses a great part of its substantial heat; and to make it pass into that state of density, it must be exposed to the action of some body, with which its base has a greater affinity than with heat. This is the general cause of the fixation of elastic fluids; and in this manner do they lose that form by becoming fixed in liquid or solid bodies. We may likewise observe that each of these fluids loses more or less heat in proportion as it becomes more or less solid in the new combination, or in proportion as this compound body is capable of containing less or more specific heat. This observation explains why bodies burn with different degrees of rapidity; why they give during combustion more or less flame or heat; and why the residues which they leave are more or less solid, &c.; which phenomena shall be more particularly mentioned in the following chapter.

Lastly, Since cold and pressure are the two means by which elastic fluids are condensed, we may perhaps be at length able, by employing intense degrees of both, to reduce all these from their gaseous state, and to obtain their bases pure and separate, by expelling the substantial heat which maintains them in fluidity. Thus we may come to know the bases of vital air, azote, *nitrogene*, or mephitic gas, hydrogenous gas, &c. This

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as been already performed on the sulphureous acid gas, which M. Monge has reduced to a liquid by means of an intense cold.

VI. Of Heat as a Chemical Agent, and the several Ways in which it may be applied to Bodies.

CHEMISTS employ heat, on account of the changes which it produces on bodies, both for decomposition and combination. Their first object should be to measure exactly the degrees of heat necessary to produce all possible alterations on any body exposed to it. These degrees of heat are generally ranked under two classes; the first comprehending all degrees of heat below that of boiling water; the second, all above that temperature. The scale of the thermometer marks out the former; our only means of determining the latter is the known fusibility of bodies.

Degrees of Heat below the point of boiling Water.

THE first degree extends from $43^{\circ} 15'$, to $54^{\circ} 30'$, Fahrenheit's scale. This temperature promotes putrefaction, vegetation, and gentle evaporation, &c. It is not seldom employed in chemical operations, as being too inconsiderable; in some macerations made during winter, however, it is necessary. It is likewise useful for the crystallization of saline solutions, which after a proper evaporation are put into caves, or other places of this temperature.

The second of these degrees, extending from about $55^{\circ} 45'$, to 77° , continues to promote putrefaction, excites a spirituous fermentation in saccharine liquors, and
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is favourable to evaporation and slow crystallization. This is the usual temperature of mild climates. It is employed for maceration, the solution of saline substances, and fermentation, &c.

The third division or degree extends from about $81^{\circ} 15'$, to $99^{\circ} 30'$. It excites the acid or acetous fermentation in vegetables; and is sufficient for the exsiccation of plants. It is used to effect some solutions of salt and to produce fermentation.

The fourth degree, which rises to $133^{\circ} 15'$, is called the mean degree of hot water: this is the heat used in the vessels called *balnea mariæ*. It destroys the organization of animal substances, and volatilizes the volatile part of animal oils, more especially of the spiritus rectior. It is employed in the distillation of those vegetable and animal substances, of which we wish to obtain the phlegm and the odoriferous part.

The temperature of boiling water 212° , is used in decoctions, and the extraction of essential oils.

Degrees of heat above the boiling point.

THE first degree or division makes glass red, burns organized substances, and melts sulphur.

The second melts the softer metals, tin, lead, bismuth, and such glasses as are most easily reduced to a state of fusion.

The third effects the fusion of moderately hard metals, such as zinc, regulus of antimony, silver, and gold.

The fourth burns porcelain, and melts the more refractory metals, cobalt, iron, and copper, &c.

The last and most intense degree exists in the focus of a burning-glass. This temperature calcines, burns
and

It vitrifies in an instant, all bodies susceptible of combustion, calcination, or vitrification. A similar heat may be excited by pouring from a blow-pipe a stream of vital air or oxygenous gas upon a piece of coal. Monge is of opinion, that by presenting to combustible bodies, when in a state of inflammation in a furnace, a quantity of compressed atmospheric air, the same effect might be accomplished which is produced by vital air. This process may be one day or other applied to very important purposes.

Though these degrees above the heat of boiling water be determined by phenomena which are well known to chemists, yet they have not hitherto been measured with all the precision that could be wished. It is therefore an object of the utmost importance to obtain an instrument capable of pointing out the exact degrees of heat employed in these operations. Mr. Wedgwood in England has constructed a thermometer for this purpose: it consists of small pieces of clay half an inch in diameter. These pieces, when contracted by the heat, fall between two graduated rulers of copper inclining towards each other upon a plate of the same metal; and thus show what contraction they have suffered, and of consequence to what degrees of heat they have been exposed (*Jour. de Phys. Ann.* 1787*.)

The heat necessary in chemical operations is produced by burning charcoal, or common mineral coal. We use on these occasions furnaces of different forms and names, according to the different purposes for which they

* There is an accurate description of this ingenious contrivance, by the inventor himself, in the *English Philosophical Transactions* for 1782.—H.

they are intended; such are the furnaces for digestion and fusion, the reverberating furnace, the wind furnace, and the cupelling furnace. A single furnace, properly made, is often sufficient for the purposes of all these; and it is then called a *Polychrest furnace*. The reader may consult on this head the Chemical Dictionary of Macquer, who has contrived a most excellent and useful furnace; Baumé's Chemistry, Pott's Lithogeognosia, and Abbé Rozier's *Journal de Physique*, in which there are descriptions of various furnaces constructed by different chemists. The flame of oil, or spirit of wine, is also employed sometimes in lamp-furnaces adapted to the purpose.

The manner in which fire is applied to bodies in chemical processes, likewise deserves some explanation. If the combustible body be applied immediately to the substance on which you wish the fire to act, the operation is then said to be managed with *naked fire*. But some intermediate body is often put between the fire and the substance exposed to its action; hence the names *balneum mariæ*, sand-bath, cinder-bath, dung-bath, &c.

The form of the vessels made use of in subjecting bodies to the action of fire, and the various phenomena exhibited by bodies under the influence of heat, have caused a great variety of operations to be distinguished by peculiar names. Such are roasting, calcination, fusion, reduction, vitrification, cupellation, cementation, stratification, detonation, decrepitation, fulmination, sublimation, evaporation, distillation, rectification, concentration, digestion, infusion, decoction, lixiviation. All these operations are performed by the action of fire, and enter into the practice of chemistry;
and

and we shall therefore give a short explanation of each of them.

Roasting is a preliminary operation, which prepares mineral substances for undergoing a series of succeeding ones, dividing their constituent particles, volatilizing some of their principles, and producing a certain alteration on their nature. Mineral ores are exposed to this process on purpose to separate the sulphur and arsenic which they contain, and to diminish the cohesion of their particles. Capsules of earth or iron, crucibles, and roasting pots, are the vessels in which it is usually performed; and it is generally exposed to the access of the external air. Sometimes, however, the operation is performed in close vessels; and two crucibles, luted mouth to mouth, are commonly employed on such occasions.

Calcination is, as it were, a more advanced stage of the process of roasting. By this process minerals are deprived of their water and salts; it likewise reduces calcareous substances to the state of quick-lime, and metals to metallic oxides. The same vessels are used in this process as in the former.

In fusion, a body is caused to pass by fire from a solid to a fluid state. The chief subjects susceptible of this operation are salts, sulphur, and metals. Crucibles of baked clay of various kinds and figures, with metallic cones and ingot moulds, are the instruments for this operation. These last are employed to give the melted matter a certain form; which they mould into bars, ingots, or buttons.

In reduction or revivification, the calces of metals are, by means of fire, with charcoal or oils, re-

stored

stored to the metallic state which they lost by calcination.

Vitrification is the fusion of such substances as are capable of assuming the brightness, transparency, and hardness of glass. Vitriifiable earths with alkalis, and the oxides of metals, are the chief of the substances subjected to it.

Cupellation is the purifying of perfect metals, by the extraction of such imperfect metals as are intermixed with them. This is performed by the addition of a certain quantity of lead to the mixture, and the exposing of it to a due heat; which vitrifies the lead, and together with it the imperfect metals of the original mixture, leaving the perfect in a pure and separate state. This operation derives its name from the vessels used in it. These are a kind of flat crucibles, resembling the small cups known under the name of *cupels*; and the substance of which they are composed, being the earth of bones, is sufficiently porous to absorb and retain the lead that is scorified by the heat.

The name of *cement* is given to powdered substances, with which other substances exposed to their action are carefully covered over. Thus, iron is covered over with powder of charcoal, that it may be converted into steel; and glass with plaster or flex, to change it into a kind of porcelain. The process by which this is effected is cementation, and requires the action sometimes of a very strong fire.

Stratification is an operation nearly similar to the preceding. It consists in arranging several solid substances, usually in horizontal layers, and intermixed with certain pulverised bodies, to alter their nature,
either

er in a crucible or in some other suitable vessel capable of bearing the action of fire. This has received the name of *stratification*, because the substances are disposed in strata or layers, one rising above another. Copper and silver are treated in this manner with sulphur, in order to effect their combination. This peculiar arrangement of substances, named *stratification*, is commonly employed preparatory to fusion, calcination, vitrification, &c.

Detonation is peculiar to nitre and the mixtures into which it enters. It is the explosion of such bodies when heated in open or close vessels. Decrepitation differs from detonation only as producing a fainter noise, which is merely a kind of crackling sound; it is peculiar to certain salts; which from a state of solution are crystallized so rapidly, that the crystals formed burst in minute pieces. This has been observed chiefly of common salt, or muriate of soda. Fulmination is a more quick and lively detonation; such as takes place in fulminating gold, fulminating powder, and in the combustion of inflammable gas and vital air, &c.

Sublimation is the volatilizing of dry, solid, and often crystallized substances by means of fire. The vessels used in sublimation are glazed earthen pots, earthen crucibles with glass heads, and pots of earth or porcelain, arranged one above another, and joined by the insertion of their necks one into another, which are known by the name of *aludels*, &c. Sulphur, arsenic, cinnabar, and many mercurial preparations, some vegetable substances, more especially camphire and flowers of benzoin, are the subjects of sublimation.

Evaporation is the action of heat on liquids, to diminish

nish their fluidity and quantity, and to obtain the fixed bodies dissolved them in a separate state. Thus, we evaporate the water of the sea and of salt springs, in order to obtain the salt which they contain. This operation is performed in capsules, jars, earthen or glass evaporatories, and silver pans, according to the nature of the liquid to be evaporated. The evaporating substance is exposed to the contact of the air, in order that the water, the body to be carried off by volatilization, may diffuse itself through the atmosphere, and that the air by its solvent power may promote the evaporation.

Distillation is an operation nearly similar, but performed in close vessels. It is used to separate volatile from fixed principles by means of fire. The distillatory vessels are alembics and retorts. The first consist of a lower vessel named a *cucurbite*, intended to contain the body to be distilled, and an upper part or capital exactly fitted to it; the purpose of which is to receive the volatilized substance, and condense it by the coldness of its temperature (which is maintained by the contact of the external air, or of water surrounding it); when water is used, the vessel containing it, into which the upper part of the alembic is immersed, is called a *cooler*, or *refrigeratory*. From the lower part of the capital there proceeds a kind of beak or spout, through which the vapours pass into a pipe, where they are condensed into a liquid: from this pipe the liquid thus obtained is conveyed into other vessels, which are commonly of a spheric form, and are named *receivers*. These receivers are of various forms and names, *matrasses*, *balloons* &c. A retort is a kind of glass, stone, or metal bottle, of a conical form, with its extremity bent, so as to make

an acute angle with its body ; and on this account has received the name *retort*. Distillation has been rather improperly distinguished into three kinds, namely, distillation ascending, *per ascensum* ; distillation descending, *per descensum* ; and lateral distillation, *per latus*. This distillation is warranted only by the exterior form of the vessels made use of. The volatilized matter has always a tendency to ascension : But distillation performed in glass or metal alembics has received the peculiar denomination of *ascending*, because the capital is placed over the cucurbite, and the vapours are seen to ascend. The distillation performed in retorts is called *lateral*, because the beak or neck of that vessel comes out at the side of the apparatus ; but the cavity of the retort in which the vapours are condensed is higher than its neck, and the distilled substance passes through that cavity, before reaching the neck. As to distillation *descending*, it was an operation which scarce served any purpose, and is now no longer used ; its products were always in a very bad state, and great part of them was lost in the process. It was performed by spreading a piece of cloth over the mouth of a glass, placing upon it some vegetable substance, and covering this with the scale of a balance, or with a capsule of metal containing some live coals. This mode of distillation was formerly used in pharmacy and perfumery, for obtaining the essential oils of some odoriferous substances. The product passing through the cloth dropped into the glass, which was always half full of water, to cool the oil ; but most part of the essence was always lost on the cloth and the metal plate above. A more useful distinction is that which regards the manner in which the substances to be distil-

led are warmed. This is performed either with *balneum mariæ*, by dipping the cucurbite in boiling water, or with the vapour, the sand, or the cinder-bath with naked fire. It is also effected by means of flame of a lamp, and by that of spirit of wine.

Rectification is a second process of distillation, object of which is to purify a liquid substance. heat is employed to carry off the purest and most volatile part, leaving the more fixed matter, which deliquesces, in a separate state; as is done, for instance, with spirit of wine, æther, &c.

Concentration is the direct contrary of rectification, its object being to volatilize part of the water, and to improve the strength of the fluids concentrated. matter to be concentrated therefore must be of superior gravity to water. This operation is performed on acids, particularly on the sulphuric and the phosphoric; it is also employed in solutions of alkalis and neutral salts.

Digestion is the exposing of substances which we wish to act gently on one another to a gentle and long continued heat. It is chiefly used to extract those parts of vegetable substances which are soluble in spirit of wine or other fluids. Chemists formerly put great confidence in this operation. Though that confidence seems to have been justly due, as it appears from many painful researches, that too active or too rapid a fire alters the nature of most vegetable and animal substances; yet modern chemists do not depend on this process with the same enthusiasm as the alchemists of old. The patient industry of these men was often employed for a series of years on one process of digestion: for by such process

they expected to perform wonders. Digestion is now confined to dyeing stuffs, elixirs, and liquors for the table; it is always successfully employed to extract the principles of vegetables and animal matters, without altering them. It is likewise useful in several operations in minerals.

Infusion is a well-known process: it consists in pouring warm or boiling water on substances of which we wish to extract the most soluble parts, and of which the texture is so slight as to be easily penetrable, such as thin bark, wood in small thin pieces, leaves, flowers, &c. It is of great use for separating substances that are easily soluble, and is often employed in chemical operations.

Decoction, or the continued ebullition of water with substances on which it acts, is used to separate those parts of bodies which are not soluble by a more moderate degree of heat. It produces considerable alterations on vegetable and animal matters; often effecting an entire change of their properties. It coagulates the lymph, melts grease and rosin, and hardens the fibrous parts of a vegetable or animal. When the chemist is well acquainted with its effects, he may employ it with considerable advantage.

In the process of lixiviation, we dissolve, by means of warm water, the saline and soluble particles of cinders, the residues of distillation and combustion, coals, and such natural earths as we wish to analyse. This operation very naturally derives its name from the *lixivial* salts which are obtained by means of it. The word *lessive* is at present used in France as synonymous with *lixiviation*, and is even more frequently used. This operation, then, is merely a solution effected by means of

heat : it is likewise nearly similar to infusion ; the difference is, that the latter is applied to vegetable animal matters ; while lixiviation is only employed to obtain substances possessing some of the properties of minerals.

These are all the operations in chemistry in which fire is called in to act a part. Formerly, indeed, every chemical operation was performed without the aid of this agent : and the science was on that account called *Pyrotechny*. But as methods of analysing bodies have been since discovered which are much less liable to error and more certain in their results ; the agency of fire is now much less used in chemistry than formerly. The action of solvents, or menstrua, even in a cold state, or in the ordinary temperature of the atmosphere, is often sufficient to accomplish the most surprising changes on natural bodies, and to afford ground for the most accurate inductions. This has been applied to the examination of salts, and vegetable matters, &c. with the happiest success. Heat is no more than a secondary mean, a kind of auxiliary that affords some assistance on such occasions. As different degrees of heat are requisite in different operations, it would be a happy circumstance if some means were contrived, by which we might be enabled to apply always the same precise degrees when the same effects were wanted. Chemists and philosophers have long wished for a furnace that might afford regular and uniform degrees of heat. Hitherto, however, the manipulations of art have been given the only means that can in any degree serve the purpose. But perhaps it is not impossible to obtain

precision which we desire, and of which the utility is so obvious. Dr Black is said to have invented a kind of furnace, by which he can command a regular and uniform heat by means of a damping-plate with holes, which may be opened or shut at pleasure. We have not received a sufficiently accurate description of it, to enable us to construct any on the same model. But we hope that a discovery so beneficial to chemistry will not be long unknown in France *.

* For measuring HEAT with the accuracy which is requisite for the purposes of science, the following means and instruments have been employed.

1. Graduated glass tubes, filled with different substances which are rarefiable by heat, and named THERMOMETERS. Of these, the THERMOMETERS filled with mercury, have now almost superseded the use of thermometers filled with fluids. The THERMOMETERS the most commonly in use, are those of *Fahrenheit*, *Reaumur*, and *Celsius*. The thermometer of *Fahrenheit* is that generally used in *Britain*. *Reaumur's* thermometer is commonly employed by the French philosophers. A degree of *Fahrenheit's* thermometer is equal only to $\frac{4}{9}$ of a degree of *Reaumur's*; and to $\frac{5}{9}$ of a degree of *Celsius' thermometer*. To reduce the degrees of *Reaumur*, to the degrees of *Fahrenheit*, multiply by 9, and divide by 4. To reduce the degrees of *Celsius* to those of *Fahrenheit*, multiply also by 9, but divide by 5.

2. The well known pyrometer of *Muschenbroek*.

3. Mr. *Leidenfrost* having observed, that the hotter a metal is, so much the more slowly will drops of water evaporate from its surface; he applied this principle to the measurement of the higher degrees of heat. On iron heated to the degree of boiling water, a drop of water evaporates in one second: On melted lead, in 6 or 7 seconds: On red-hot iron in 30 seconds. At 520° Fahrenheit, the hot body evaporates a drop of water in 89 seconds.

4. The purest clay shrinks in the fire, in proportion to the heat applied to it. And upon this principle, the ingenious Mr *Wedgewood* constructed one of the best pyrometers with which we are acquainted. It consists of a graduated gauge; the rule of which is divided into 240 equal parts, each being $\frac{1}{10}$ of an inch;—and of other pieces of the same clay, baked at a red heat, and of given dimensions, which are applied to the heat

to be measured, and are then again applied to the graduated gas which shows how much they have shrunk, and by consequence affords a measure of the heat to which they have been exposed.

5. The instrument of *Messrs. Lavoisier and De la Place*, for measuring heat by the melting of ice, is perhaps more accurate than any other pyrometer. It consists of three circular vessels, nearly inscribed in each other; and affording three separate capacities, or receptacles. The *interior* cavity, formed by an iron grating, upon support of the same metal, and closed on the upper part by a cover, is designed for the reception of the body subjected to experiment. The *middle* cavity contains the ice, the melting of which is to measure the heat given out by the body under experiment. The *exterior* cavity contains ice intended to preclude any heat out of the atmosphere, from passing into the *middle* ice, which is to be melted by the heat of the *interior* body alone. The water produced by the melting of the *middle* ice is weighed; and its weight affords a measure of the heat given out.

For the description of Dr. Black's furnace, see *the Edinburgh Dispensatory*, 4th edition, pages 48, 49, 50, 51, with fig. 7, 8 of Plate I.—H.

C H A P. VI.

Of Atmospheric Air.

COMMON air is an invifible, inodorous, infipid fluid poffeffed of gravity and elasticity, extremely fufceptible of motion, and capable alfo of rarefaction and condensation, which encompaffes our globe to a certain height, and compofes the atmofphere. It likewife infinuates itfelf into, and occupies, the interftices or pores between the integrant parts of bodies. The atmofphere which encircles our globe is far from being pure air. As it receives all the vapours that arife from the furface of the earth, it may be confidered as a kind of chaos, or heterogeneous mixture. We fhall foon fee, however, that its nature is at prefent pretty well known. Water, mineral exhalations, and elastic fluids difengaged from minerals and metals, are inceffantly carried up into the atmofphere, and may be faid to conftitute its elements. The objects of attention in a natural hiftory of the atmofphere are, its height, the precise degree of which is not yet accurately determined; the variations to which it is liable; its gravity; its different ftrata; the effects of its rarefaction and dilatation; winds, and meteors. But thefe come under that part of phyfics which is known by the name of *meteorology*, and form no part of the province in which we are engaged. Yet as air has a powerful influence on chemical

mical phenomena, and it is of considerable importance to know the nature and extent of that influence, we shall here examine both the physical and the chemical properties of air.

§ I. *Of the Physical Properties of Common Air.*

FLUIDITY, invisibility, insipidity, gravity, elasticity, and negation of smell, may be considered as the physical properties of air. Each of these merits a particular examination.

Such is the rarity of this fluid, that it readily yields to the slightest impulse, changing its situation on the smallest motion of bodies immersed in it. This kind of fluidity depends on the degree of its aggregative force ; and as it is not confined to atmospheric air, but is found to characterise several other fluids, these are called *aëriform fluids*, or *gases*. What constitutes the peculiar nature of aerial aggregation, is, incapacity to pass into a solid state ; contrary to what most liquid bodies are susceptible of. But this, however, no more is to be understood, than that hitherto we have not been able to apply to it any degree of pressure or cold sufficient to accomplish this effect. This is the distinguishing characteristic of permanent gases. The fluidity of the air exposes it to those frequent and rapid motions which constitute the winds. It is not, however, capable of penetrating into all bodies. Transparent matters, through which light readily makes its way, are secure against the impulse of air. Water, solutions of salts, oils, and spirit of wine, pass through many bodies whose texture is such as not to admit air. Those liquid substances

are endowed with the property of dilating such, enlarging their pores, and diminishing the densities of their contexture; of which air is deficient.

When confined in vessels, is absolutely invisible, and cannot be distinguished from the glass that contains it: when entirely filled with this substance, vessels appear to the eye a seeming vacuum. It owes this property of invisibility to its tenuity and the ready passage which it affords to the rays of light: these are reflected, without being reflected by it. And it is therefore destitute of colour; though some natural philosophers were persuaded themselves that they discovered large quantities of it to be blue.

Naturalists have uniformly considered air as an insensible fluid. Yet, in attending to what happens, when the organs of animals are exposed to the contact of this fluid, as in the instance of wounds, and on other similitudinations, we cannot but observe that it has a kind of agency; of which we are not generally sensible, because we are so constantly accustomed to it. Wounds, when uncovered and exposed to the air, are attended with an acute pain. A new-born infant expresses by its cries the disagreeable sensations which it receives from the first contact of the external air. This property of the air is to be considered as the reason why wounds that are exposed to it, uncovered, remain long open. Atmospheric air, in the same manner, retards the growth of new bark on such vegetables as have been stripped of their covering. In order that they may regain their bark, they must be covered with some body which may exclude the air.

Air is perfectly inodorous. If the atmosphere sometimes affect our organs with a kind of fetid smell this is to be attributed to the extraneous bodies that are mixed with it ; as may be observed in mists and vapours.

The gravity of air is one of the finest discoveries of natural philosophy : the fact was never certainly known till about the middle of the last century ; though Aristotle indeed is said to have known that a bladder was heavier when filled with air than when empty. The ancients had no distinct idea of the gravity of air, but ascribed to a certain occult quality, which they called *abhorrence of a vacuum*, all those phenomena which depend on the weight of this body. Certain workmen finding it impossible to raise water by a pump above the height of two and thirty feet, were induced to consult the famous Galilæo on the occasion. He was amazed at the phenomena. Death prevented him from discovering the reason of it ; but this was afterwards discovered by his disciple Torricelli in the following manner. He reflected, that water could not rise in a sucking pump, without being impelled by some exterior cause, the pressure of which forced it to follow the motion of the piston. The influence of that cause must be limited, since it never raised the water above the height of two and thirty feet. Therefore, if it were to act upon a body of greater specific gravity than water, it would raise that body only to a height proportioned to its gravity. He next took a glass tube six and thirty inches in length, and hermetically sealed at one end : this he filled with mercury, holding the close end down, and stopping the upper end with his finger,

finger, after he had poured in the mercury : then, turning the close end up, he immersed the other into a vessel full of mercury ; and upon removing his finger, found that part of the mercury in the tube had fallen down into the vessel, but that a considerable quantity still remained ; which after various oscillatory motions, at length settled at 28 inches. By comparing this with the height of 32 feet, to which water rose in the pumps, he perceived that the difference of the elevations to which these two fluids rose was in exact proportion to the difference between their specific gravities ; for the proportion of the specific weight of mercury to that of water is as 14 to 1, and the water rose 14 times as high as the mercury. It was not, however, till after long reflection, that he began to conjecture the weight of the air to be the cause why fluids were thus suspended in a pump. Nor was the existence of this weight certainly determined, till after the ingenious experiment which Paschal directed to be made in France.

This celebrated philosopher imagined, that if it were actually the weight of the air which caused water to rise to the height of 32 feet in a pump, and mercury to the height of 28 inches in Torricelli's tube, these fluids would rise to different elevations on the summit of a mountain and in a vale ; as in the former case the weight of the atmosphere must be diminished. In consequence of this suggestion of Paschal's, Perrier made the famous experiment which finally determined the opinions of philosophers concerning this phenomenon, on the 19th September 1648, at the foot and on the summit of the mountain Puits de Dome, in Auvergne. The barometer, or Torricellian tube, being filled with

mercury, and fixed to a scale of 34 inches, divided into inches and lines, the mercury rose about four inches higher at the foot of the mountain than on its summit, which is 500 toises higher. From this it was determined that the mercury varied about an inch for every hundred fathoms: and the barometer has since that time been very successfully applied to the measurement of the height of mountains.

The weight of the air has an influence on many physical and chemical phenomena. It compresses all bodies, and resists their dilatation; it opposes the evaporation and volatilization of fluids: and to it the waters of the sea owe their liquidity; for they would otherwise be reduced to vapour, as may be observed of fluids placed in the vacuum produced by the air-pump. Air, by its gravitation on our bodies, retains both the solids and fluids in their proper places: and the blood often bursts through the skin, or from the lungs, on the tops of mountains, occasioning hemorrhagies; because the gravity and pressure of the air are there considerably diminished.

Lastly, air possesses great elasticity. However strongly compressed, it instantly returns to its former rarity as soon as the compressing cause ceases to act upon it. The truth of this assertion is proved by a great many experiments. We shall here mention only the most obvious and most conclusive of those physical facts by which it is evinced. Take a tube of glass, bent into a form somewhat like the letter U, and close at one end; fill it nearly up with air, and then pour in a quantity of mercury to prevent the air from escaping: you may thus compress the air so as to know what degree of compression

compression this elastic fluid is susceptible of, by comparing the diminution of its bulk with the height of the column of mercury employed to compress it. A football, which being filled with air rebounds from any hard body, affords another proof of the elasticity of this substance. The fountain by compressed air, gives an instance of the same fact: Air being compressed into the superior part of this vessel, is soon dilated by the heat of the atmosphere, so as to force the water out by a tube to a considerable height. Lastly, the wind-gun, the effects of which are generally known, is another instrument for showing the elasticity of air, and the compression of which it is susceptible. It is computed, that air may be compressed into $\frac{1}{11}$ th of its ordinary bulk.

Heat, which rarefies it by counteracting any compressive force to which it is exposed, shows that it is no less capable of enlarging its bulk by dilatation. If a bladder full of air be exposed to the heat of a furnace, the air will be dilated so as to burst the bladder with a violent explosion. This is likewise often the cause of the bursting of the vessels in chemical operations; against which, however, proper precautions are now adopted. The diminution or total abstraction of the weight of the atmosphere, which is effected by the air-pump, affects a bladder filled with air in the same manner as a violent heat.

The reader will naturally conclude from this account of the gravity and elasticity of air, that many of the variations which we observe in the atmosphere and on the barometer are owing to these properties. In fact, the inferior support the superior strata of the at-

mosphere ; and the compression of a stratum of air is always smaller or greater in proportion as it occupies an higher or lower situation. Heat also, which is constantly varying, has the power of modifying this gravity and elasticity. These are the reasons why air is found to be lighter, keener, and more agitated, &c. on the tops of mountains, than on plains and other less elevated situations. To understand those astonishing phenomena which the barometer offers to our attention, we must study the gravity and elasticity of the atmosphere, as well as the changes to which it is liable, from the influence of heat. M. de Luc and M. Saussure, have for some years paid much attention to this class of the phenomena of nature.

§ II. *Of the Chemical Properties of Common Air.*

THE properties above described are all that were anciently considered by philosophers as belonging to air. Several chemists, at the head of whom Van Helmont, Boyle, and Hales, deserve to be ranked, observing that air, or at least a fluid with all the apparent properties of air, was obtained in the analysis of many natural bodies, inferred, that this element subsisted in those bodies in a combined and fixed state. Hence arose the name *fixed air*, which was at first given indifferently to all the elastic fluids obtained in chemical operations. The above mentioned philosophers supposed these substances to be of the same nature with atmospheric air : But Dr Priestley has discovered a number of elastic fluids, which, though apparently the same with common air, yet differ from it in many respects.

We

We must then have recourse to other qualities, if we wish to distinguish atmospheric air from the other aëri-form fluids, which like it are invifible and elastic. Its chemical properties afford the only criterion on which we can establish this diftinction.

In examining the diftinctive properties of air, we find two which are peculiar to it, and may very well ferve to mark its character; one, its being favourable to combustion or inflammation; the other, its ferving to maintain animal life in refpiration. Let us carefully examine thefe two great phenomena.

It is exceedingly difficult to give a good definition of combustion. It is not one, but a number of phenomena which combuftible bodies offer to our obfervation, when they are heated and expofed to the action of the air. The chief of them are heat, motion, flame, rednefs, and the change of the nature of the fubftance that is burnt. There are many varieties among combuftible bodies. Some of them burn briskly, and afford a brilliant flame, fuch as oils, wood, refinous and bituminous fubftances, &c.: others burn away without producing a difcernible flame; as for inftance many of the metals, and charcoal which has been properly prepared: others again are confumed by a flow motion, fcarce obfervable, almoft without feeming to be on fire, but always with a degree of heat;—fuch is the combustion of fome metallic matters. Combustion, however, takes place equally in all thefe inftances; and the body which has been once burnt in any of thefe ways, is no longer fufceptible of inflammation. The refidue is always heavier than the combuftible body. This may be eafily proved to be the cafe with fixed combuftible bodies. But again, thofe

of which the inflammable matter is of a volatile nature, burn with more rapidity than the former, and their fixed residue wants much of the original weight. From this it may perhaps be thought, that these last lose much of their weight in burning: but it is only a seeming loss they suffer; and there are no combustible bodies of which the residues are not weightier than before combustion. For, what remains fixed on such occasions is not the only residue of the combustible body; a considerable part of volatile combustible bodies is converted into elastic fluids, which ascend and are diffused through the atmosphere: and were we to suppose that these leave no other residue but what appears after their combustion on the spot, or in the vessel where they were burnt, we must believe what is impossible, that they afford no residue. *Æther* and spirit of wine burn away without leaving the smallest particle; but the substance into which they are converted is volatilized and diffused through the atmosphere. When means are employed to collect it, it is found to possess more gravity than the combustible body from which it was produced. Thus, by burning sixteen ounces of highly rectified spirit of wine under a chimney adapted to the worm-pipe of a still, M. Lavoisier obtained eighteen ounces of water as the product of this combustion. Oils, resins, &c. present the same phenomenon. Thus, the cinders of burnt wood are not the whole of the residue which it affords, the rest ascends in the air: one part, not being thoroughly burnt, becomes soot; and the other mixing with the atmosphere, is condensed into water, or deposits in it some other elastic fluids. It is therefore an e—

established truth in chemistry, that all combustible bodies acquire additional weight by being burnt.

To understand how this addition of weight is acquired, we must attend to another of the phenomena of combustion, which it will be necessary to explain more at large. Combustion can never take place without the help of air, and is always in proportion to the purity and the quantity of that fluid. Ever since the discoveries of Boyle and Hales, philosophers have been struck with this fact, and have proposed a variety of hypotheses to explain it. Boerhaave thought that air contributed to combustion by operating on the surfaces of combustible bodies, so as to dissect them, if the expression may be allowed, into their component particles. This hypothesis did not explain why the same air could not always promote combustion. M. Morveau supposed this last fact to depend on the extraordinary rarefaction of the air by heat; in consequence of which, it acquired such elasticity as to prevent the combustion of inflamed bodies by forcible compression. But he offered this ingenious hypothesis at a time when it was impossible to distinguish the true cause of the phenomenon. M. Lavoisier, by a series of fine experiments on the calcination of metals with determinate quantities of air, has proved, that, as John Rey the physician had before observed, so much air is absorbed during calcination, that the calcined metal acquires precisely that quantity of weight which the air loses during this process; and that the portion of air absorbed actually remains in the metallic calx, as the calces of mercury may be reduced merely by expelling that fluid. Other facts led him still farther. He observed, with Priestley, that the air which remains after the process of

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calcination

calcination or combustion, can no longer serve to promote new processes of the same kind ; that it extinguishes flame, suffocates animals, and, in a word, has acquired a different nature. He likewise found that its diminution is exactly proportioned to the quantity absorbed by the combustible body. On the other hand, air extracted from metallic calces has been found to be three or four times purer than atmospheric air. It not only promotes combustion, but even renders it much more rapid. A given quantity of the former will serve for the inflammation and total combustion of three or four times that quantity of matter which may be consumed by the help of the same portion of the latter. To this singular fluid obtained from the calces of mercury, Dr Priestley, who first discovered it, gave the name of *dephlogisticated air* ; because he considered it as atmospheric air deprived of the phlogiston, which, according to him, is diffused through the whole atmosphere. Its phlogiston he believed to be retained by the mercurial calces, which are gradually reduced as this elastic fluid is disengaged by heat. But as that name may lead to a false idea of its nature, we shall give it the name of *vital air* ; for it alone is the great agent in respiration, as well as combustion ; and to use the expression of M. Lavoisier, it has four times as much of the genuine nature of air as common air has.

From thus observing, that air is absolutely necessary to combustion, and that part of the air necessary to the calcination of metals remains in the calces, M. Lavoisier was at first led to think, that combustion consisted in the absorption of pure air by the combustible body. Abstracting the water and vapours contained in atmospheric

air, he considered the substance that remained as a compound of two very different elastic fluids. One of these, which is the only genuine air, and which promotes combustion by precipitating itself into the combustible body, and uniting with it, is vital air. It generally composes a fourth part of the atmosphere, and sometimes even a third part, when it is in its purest state. The other fluid is deleterious to animals, and extinguishes flame; and it constitutes three-fourths or two-thirds of the atmosphere: it was at first named mephitic air. When a combustible body is exposed to the air and kindled, a portion of the vital air in the atmosphere becomes fixed to that body, and its combustion continues till it absorbs all the vital air immediately around it. The residue of the air, after it has lost this pure vital part, can no longer contribute to combustion. It regains this power on being again qualified with a due quantity of pure air extracted from nitre or a metallic calx. This elegant theory proposed by M. Lavoisier in the years 1776 and 1777, appeared to explain all the phenomena of combustion. It accounted for the additional weight acquired by metallic calxes, and the extinction of flame by air that had been already employed in combustion. But M. Lavoisier, after continuing his experiments upon the subject, has thought proper to modify and enlarge it by new observations. The bright flame which is observed on immersing a burning body in vital air, or on pouring this fluid on the surface of a flaming substance (which may be done by means of an ingenious machine of his invention) made him desirous of knowing whence it proceeded, and whether, according to the theory of Stahl, it were owing to the disengagement of phlogis-

ton. He inquired into this with the more attention because the celebrated Macquer had still persisted, notwithstanding *his* discoveries, in maintaining Stahl's theory, but had laboured to reconcile *his* theory with that of the father of philosophical chemistry. Macquer was of opinion, that pure air became fixed in combustible bodies in consequence of their phlogiston being disengaged; and that pure air and phlogiston were reciprocally precipitated; the one from the atmosphere into the combustible body, the other from that body into the atmosphere: in every process of combustion pure air extricated phlogiston into a state of liberty, and assumed its place; and in the reduction of metals, phlogiston disengaged pure air and occupied the room which it had formerly possessed. M. Lavoisier observing that the bright sparkling flame before mentioned, which affords the strongest indication of the presence of light or the matter of fire in a state of activity, seems rather to surround the exterior part of the body in combustion, than to proceed as if it were disengaged from it;—has been led to think that light and heat are separated from vital air, in proportion as it is absorbed by the body in combustion. His present opinion is, that vital air, like all other aëriform fluids, is a compound, consisting of a certain principle susceptible of solidity, and of fire or the matter of heat; that to its possessing the latter it owes its state of elastic fluidity; and that, being decomposed in combustion, its fixed, solid principle, by entering into combination with the combustible body, increases its weight and changes its nature,—while the matter of fire that it contains is disengaged under the form of light and heat. Thus, the

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modern doctrine has bestowed on vital air what Stahl attributed to phlogiston. If combustion consist in the disengagement of fire, it is the air, not the combustible body, which burns. As to the principle which, in combination with the matter of fire, constitutes pure or vital air, though M. Lavoisier have not fully explained its nature, yet as it is often known to form acids by entering into combination with combustible substances, he has conferred on it the name of *oxygene* *. With this base, the sulphuric, arsenic, and phosphoric acids, &c. are produced in the combustion of sulphur, arsenic, and phosphorus, &c. In all these bodies it is still the same. It is to be observed, that according to this new theory, the vital air which is obtained from metallic calces did not exist in these calces under that form. It becomes such, in consequence of the combination that takes place between the heat and light communicated through the vessels in which the calces are contained during this process, and the *oxygene* by which they are constituted calces.

Such is the present state of chemical doctrine concerning the nature of atmospheric air, and its influence on combustion. The theory of which we have given an account, is daily gaining new strength. The objections urged against it have but little weight: they even show, that if its opposers were better acquainted with it, they would cease to raise their voice against it, and that when

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* M. Lavoisier gave it at first the name of *oxigyne*; but finding it necessary to apply an analogous name to some other substances, before known by improper denominations, we have changed the *gyne* into *gene*, as more expressive of its Greek derivation.—F.

it shall become generally known, it will be unanimously received by the learned.

Respiration is a phenomenon nearly resembling combustion. Common air is decomposed in the one as well as in the other; that it may contribute to either, it must contain a certain quantity of vital air. When it is deprived of all its vital air, the mephitic residue is fatal to animal life. Respiration is in fact but a slower combustion, in which part of the heat of vital air enters the blood as it passes through the lungs, and is by it conveyed through the whole body. In this manner animal bodies receive their supplies of heat, which are absolutely necessary, as they are constantly giving out the heat which they contain, to the atmosphere and other surrounding bodies. To maintain the heat of the blood is, therefore, one of the chief purposes of respiration; and this beautiful theory explains why the blood of those animals that respire either no air or but very little, is always cold.

Messrs. Lavoisier and De la Place have discovered another service which the air performs in the act of respiration. It absorbs a certain principle that exhales from the blood, and appears to be of the same nature with coal. That substance being reduced into vapour enters into combination with the oxygenous part of vital air, and forms the carbonic acid which is discharged from the lungs by expiration. This fact,—the formation of the carbonic acid in the atmospheric air respired by animals, at the same time when the *mephitic* air is separated,—explains why such dangerous effects ensue from the shutting up of a number of persons together in close places; such as happens in thea-

tres, hospitals, prisons, and the hold of a ship, &c. After this, we can no longer be surprised at the noxious effects of air altered by respiration, by which persons of delicate constitutions and great sensibility of nerves are particularly liable to be affected.

The atmosphere which encompasses our globe appears, therefore, to be suffering continual alterations from the two great phenomena of combustion and respiration. That fluid would be very inadequate to these two great purposes, were there not other means provided for renovating the atmosphere, and maintaining it with constant supplies of vital air. In the following chapter, and in the third part, we shall see that the organs of vegetables are designed by nature to extract this vital air from water, as well as to pour it into the atmosphere, when struck by the rays of the sun.

§ III. *Of the distinguishing Properties of that Mephitic Air, or Gas Azote, (or Nitrogene *,) which enters into the Composition of Atmospheric Air.*

FROM the preceding account of atmospheric air, it appears to be a compound body, consisting of two gases or elastic fluids; one of which maintains combustion or respiration, but the other is entirely unfit for either of these purposes. The first, which is named vital air, exists in the proportion of 0,27 or 0,28; while the latter amounts to 0,73 or 0,72. We have asserted the first to be a compound of the caloric and the

* I think *nitrogene* adopted by M. Chaptal, a more correctly analogical name for this gas than *azote*; unless farther discoveries should induce us to adopt rather the term *alkaligene*, as expressive of a more general property belonging to it.—H.

the oxigenous principles ; the second, like all other gaseous bodies, is also a compound of the caloric principle with a base susceptible of solidity. To this elastic fluid, which constitutes more than two thirds of the atmosphere, M. Lavoisier at first gave the name *mosfette* ; because it extinguishes combustion, and destroys animals. But since all gasses, except vital atmospheric air, are equally noxious, and are therefore all equally intitled to the name of *mosfettes* or *mephitics* which has been always applied to elastic fluids unfit for respiration ;—we have adopted the words *gas azote* as the peculiar denomination of *this* aëriiform fluid : and we may of consequence apply the substantive *azote* or the term azotic principle, to the base of this gas which, like the oxigenous principle, the base of vital air, becomes fixed by entering into combination with a number of substances. In order to give some idea of the nature of this gas azote, we shall mention a few of its properties. It is somewhat lighter than common air, and therefore occupies the upper part of rooms in which the air hath been altered by combustion or respiration. Though so noxious to animals, in the state of elastic fluidity, yet the azotic principle its base, is one of the component principles of animal bodies ; from which it is extracted in great abundance. It is likewise one of the constituent parts of volatile alkali, or ammoniac, and of the nitric acid it appears to be absorbed by vegetables, and perhaps also by animals. It is highly probable, that the same principle enters into the composition of all alkaline bodies, and may be considered as a genuine *alkaligenous* principle, in opposition to the base of vital air

to which we have given the name of the *originous principle*. Thus we are led to consider the atmosphere as a vast reservoir of *acidifying and alkalifying* principles, though it be itself neither acid nor alkaline.

Here we can only mention these properties ; in the succeeding part of the work they shall be more particularly explained. Here we have only endeavoured to point out the difference between the two fluids of which our atmosphere consists, and to fix the reader's attention on the nature of each as distinct from the other,

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C H A P. VII.

Of Water.

WATER was long thought to perform an important part in almost all the phenomena of nature, and to be capable of assuming a vast variety of forms, and entering into many combinations, without suffering any alteration of nature, or becoming unable to resume its original state. But the late researches of Messrs Lavoisier, Meunier, de la Place, and Monge, have discovered that water, like air, is compounded of more simple principles which may be obtained separate. The period of this important discovery constitutes a glorious æra in the history of chemistry. We shall afterwards see by what means these philosophers accomplished the analysis of water. Let us first consider the physical properties of this body.

§ I. *Of the Physical Properties of Water.*

PHILOSOPHERS define water to be an insipid, ponderous, and transparent fluid, without colour or elasticity, extremely susceptible of motion, and capable of passing through the various states of aggregation, from the solidity of ice to the tenuity of vapour or elastic fluidity.

It is found in almost all natural bodies ; but nature has united it with many substances with which art has
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not yet learned to make it enter into combination. It is obtained from wood, and from the most solid bones ; it is known to exist in the hardest and most dense calcareous stones ; it constitutes the most considerable part of animal and vegetable fluids, and even enters into the composition of the solid parts of such bodies. These are the facts which gained it a place among the number of the elements.

The natural philosopher views it as existing in masses over the globe, filling up its cavities, or furrowing its surface. Its history comprehends that of the eternal ice which covers the summits of some lofty mountains and the polar seas, of lakes, rivers, rivulets, springs, clouds, rain, hail, and snow. It is distinguished into terrestrial and atmospheric water. It attracts the curious inquiry of the philosopher, in its passing successively from the surface of the earth into the atmosphere, and from the atmosphere upon the rising heads of hills ; and again, in its gathering into streams, producing springs, fountains, and rivers ; and in the last form, holding its headlong course to its great reservoir the sea. Observing the phenomena of this immense mass of water, we behold it agitated with the most tremendous motions ; we see its fluctuations and currents sometimes raising awful liquid mountains ; we see it sometimes encroaching on the limits of the earth, and sometimes retiring within its ancient boundaries. Here new islands spring up from its depths ; there the foundations of isles of ancient name are sapped, and they swallowed up in its bowels. If we trace its action in subterraneous cavities, we there find it engaged in humbler labours, producing salts and crystals, and depositing them
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in the clefts of the rocks. All these objects must come under our attention in pursuing the natural history of water. But we must first examine its physical and chemical properties.

The most remarkable of these is its being susceptible of various forms, and becoming by turns a solid, a liquid, or a vaporous body. Let us consider it under one of these three modifications.

I. Of Water in the State of Ice.

Ice seems to be the natural state of water; chemistry at least, we consider that, as the natural state of any body, in which its aggregative force is the greatest. But as it appears much more frequently in a liquid state, liquidity is still considered as the natural state of water.

Several phenomena highly worthy of observation occur in the formation of ice.

1. The change of a liquid into a solid body takes place on the freezing of water, occasions the expansion of some degrees. In a thermometer immersed in boiling water, the mercury rises some degrees above the zero; while in another, in the open atmosphere of the same temperature, it either remains fixed at that point, or sinks below it. It appears, therefore, that part of the heat which is fixed in water in a liquid state, is disengaged and escapes into the atmosphere when it assumes a solid form; and the specific heat of ice is actually less than that of water. A similar disengagement of heat is observed in the crystallization of salts.

2. The external air promotes the formation of ice. Water in a close vessel freezes but very slowly; exposed to the open air, even in the same temper-

Ice will almost instantly appear. A similar phenomenon is observed in the crystallization of salts: many fine solutions, which in close vessels are maintained in this state, will almost in an instant display crystals, if you open the mouth of the vessels and expose them to the contact of the atmosphere.

3. Gentle motion is favourable to the production of ice. The same thing is observable of saline crystallizations. By shaking some solutions, which otherwise would not produce crystals, we sometimes see these appear while the shaking is continued. I have often observed this in solutions of calcareous nitrate and muriate. These analogies between the formation of ice and that of saline crystals prove, that the former is actually a species of crystallization.

4. The bulk of a piece of ice appears to be greater than that of the water of which it is formed; bottles and other glass vessels are burst in consequence of the swelling of liquids with which they are filled. But this effect is to be ascribed not to the water, but to the air which is disengaged from it during its congelation.

When ice is formed, it is distinguished by the following properties.

1. It has been observed by M. Mairan, that when formed by a slow congelation, its crystals are in the form of needles crossing each other at angles of—from 60° to 120° . Sometimes its crystallization takes a regular and determinate form. M. Pelletier, a disciple of M. D'Arcet's, and member of the college of pharmacy, observed in a piece of fistulous ice, crystals in the form of flat quadrangular prisms, terminating in two pyramidal summits, but with great variety.

ther hand, when ice is suddenly formed, and in large masses, it becomes one irregular solid, exactly like that produced when solutions of salts are pressed close together, and suddenly cooled *.

2. Its solidity is so great, that it may be reduced to powder, and carried about by the wind. In very cold climates, ice becomes so hard that it may be hewn into pieces like stone, and used in building. Nay we are even confidently told that masses of ice have been hollowed into cannons, and charged and discharged several times before melting.

3. Its elasticity is very great, much greater than that of water in fluid state. Throw a piece of ice on a solid plane, it rebounds from it like any other hard body.

4. It has a keen, sharp taste, nearly approaching to causticity. Every person knows what kind of sensation ice gives when applied to the skin. Physicians employ it in external applications as a tonic or discutient, &c.

2. Its gravity is less than that of the fluid on which it swims; which seems to be occasioned by its containing a greater quantity of air in proportion to its bulk. The same phenomenon takes place on most of those bodies that admit of concentration by cold, and fusion by heat, such as butter, fat, wax, &c. and still arises from

* M. Sage informs us, that a piece of ice containing within it unfrozen water; if broken so as to suffer the water to run out; exhibits in its cavity beautiful, tetrahædral prisms, terminating in four-sided pyramids.

M. Macquart relates, that when it snows at Moscow, in a humid state of the atmosphere, the air is observed to be loaded with crystallizations, regularly flattened, and thin as a leaf of paper. These crystallizations consist of fibres diverging into six different rays from a common centre. H.

in the same cause; for every substance is by itself more dense and weighty in its solid than in a fluid state.

i. Its transparency, at least in irregular masses, is obscured by air bubbles. You may be convinced of this by examining a piece of ice attentively; and if the cavities be opened under water, the air which they contain will be seen to issue in bubbles from its surface.

. It melts at some degrees above 32° ; the liquefaction proceeding gradually from the surface to the centre.

. Passing from a solid to a liquid state, it produces a vapour in the surrounding atmosphere. Modern chemists think that it absorbs heat when it melts: and that the quantity of the caloric principle which becomes fixed upon that occasion, is equal to the quantity of heat engaged when it passes from fluidity into the state of solidity. The same phenomenon is common to all fluid bodies that can be condensed into solids, and again reduced to fluidity by the variation of their temperature.

II. *Of Water in a Fluid State.*

THE properties of water in a fluid state are very different from those of ice.

i. Its taste is much fainter, for it is generally considered as insipid. And yet people that drink much of it, distinguish differences in its taste at different times, which shows that it is not absolutely insipid.

ii. Its elasticity is less than that of ice. Some experiments of the Academy *del Cimento*, have even caused the property to be entirely denied to it. But the Abbé Mongez has proved the elasticity of water by a series of ingenious researches; and has even

experiments of the Academy admit of an inference directly opposite to that which has been deduced from them. For the spheres of metal, which had been filled with water for those experiments, continued to exude liquid drops after being taken out of the press; which could not have happened if the water had suffered no compression.

3. In the state of a liquid aggregate, water is more under the influence of the affinity of composition. From this circumstance it has obtained the name of the great solvent of nature. It does indeed enter into union with many bodies, and even contributes highly to the mutual combination of bodies.

4. It seems incapable of combination with light, which passes through it without producing or suffering any alteration. Light is known to change its course in passing through water, so as to assume a more perpendicular direction.

5. Heat dilates it to a gaseous state. Its passing from a liquid state to that of aëriform fluidity, constitutes ebullition. The cause of this phenomenon is, that, part of the mass of water under examination having assumed the form of an elastic fluid, the heat no longer suffers it to remain in union with that which is still liquid: each bubble rises from the bottom of the vessel, and ascends into the atmosphere, in obedience to the action of heat. I have explained the cause of ebullition at large in my *Memoires de Chimie*, published in 1784, page 334.

The weight of the air has a remarkable influence on the ebullition of water. It opposes its dilatation and evaporation: And in proportion as the gravity of th

air is less or more, the resistance which it opposes to the volatilization of water must be weaker or more powerful. Thus, Fahrenheit observed, that the temperature of water in a state of ebullition is not always the same. In order then, to know with greater certainty the precise degree of heat at which water boils, we must consult the barometer as well as the thermometer, and we shall find the requisite heat always proportioned to the weight of the air.

The influence of the weight of the air on the rarefaction and ebullition of water becomes more remarkable when we make our observations at various heights in the atmosphere. Thus, *cæteris paribus*, water boils easier on the summit of a mountain than in a valley or on a plain; the heat requisite to produce ebullition being less in the former situation than in either of the two latter. All fluids are easily rarefied at very elevated heights; for this reason, liquids that are highly volatile, such as spirit of wine, æther, and alkaline or ammoniac gas, lose much of their strength on the tops of mountains; a fact which has been generally observed by natural philosophers, and fully determined by an observation made by M. de Lamanon, at the height of more than 1800 toises above the level of the sea. Abstract the weight of the atmosphere with the pneumatic engine, and you may heat water to ebullition, and reduce it to a vapour, without raising it to the temperature of 122° .

Lastly, A third circumstance, beside the heat and the gravity of the atmosphere, which affects the ebullition of water, is the dryness or humidity of the atmosphere; but as the influence of this circumstance is

tirely chemical, we shall reserve the consideration of it to the next section.

6. Boil water in a close vessel, and with a suitable apparatus for collecting the vapours; let these be condensed by cold, and conducted into a receiver; what is thus obtained is distilled water. By this means water is obtained pure, and separated by those earthy and saline matters which almost always alter it, but are now left in the bottom of the vessel. Chemists, who always need pure water for their experiments, provide themselves with it in this way. They pour river or fountain water into a cucurbite of copper tinned over within: this they cover with a capital inserted into a refrigeratory filled with very cold water, for the purpose of condensing the vapours; which are thus caused to pass in drops into glass-vessels prepared for their reception. But in order to obtain distilled water in the greatest purity, an alembic peculiarly adapted for this purpose must be employed. To abridge the process of distillation, this vessel should be prepared on particular principles; the cucurbite should be broad and flat, and the capital of the same form. Water thus distilled is perfectly pure. Chemists formerly made use of snow or rain water; but these are now known to contain solutions of some extraneous substances.

Distilled water has an insipid taste, and when drunk oppresses the stomach with a kind of weight; but after being exposed to the open air, and briskly shaken, it recovers its taste, and may be drunk with safety. Distillation does not alter water, it only deprives it of the air which is always united with it in its ordinary state, and communicates to it that lively fresh taste which renders

renders it potable. Boerhaave distilled a quantity of water 500 times successively, without being able to discover any alteration upon it. Some philosophers have at different periods asserted, that water is changed into earth; because, at each new distillation, it leaves a certain quantity of an earthy residue in the bottom of the vessel. M. Lavoisier has made a series of the most accurate experiments, with a view to determine this. By weighing the glass vessels employed in the process of distillation, and doing the same with the water distilled and its residue, he has discovered that this earth is nothing but a part of the matter of the vessels ground down by the action of the water.

III. *Of Water as an Elastic Fluid.*

WHEN water is reduced by the action of fire into the state of vapour or elastic fluidity, it acquires new properties which distinguish it from what it was under the two former modifications.

1. If the air into which it is received be above the temperature of $65^{\circ}, 45'$, and not overcharged with humidity, it becomes perfectly invisible.

2. If the temperature of the atmosphere be below $54^{\circ}, 30'$, and, if it be already loaded with moisture, the watery vapour forms a white or grey cloud, which is very plainly distinguishable: The reason of this is, that it is not dissolved in the humid air, as will be afterwards shown; but a true precipitation actually takes place.

3. Its dilatation is so considerable, that, as M. Wath assures us from the most accurate con-

pies, in this form, 800 times the space which it fills when liquid.

4. Such is its elasticity, that when compressed, it produces dreadful explosions; and is happily employed in mechanics to move enormous masses. Its utility in that valuable machine the steam-engine is well known both to philosophers and artisans.

5. Agreeably to one of the most uniform laws of the affinity of composition, it has a greater tendency to combination in this state, in which its aggregative force is weakest, than in the two former. Chemists have frequently occasion to observe with what rapidity water in the state of vapour dissolves salts, softens mucous substances, corrodes and calcines metals, &c.

6. It is entirely dissolved in air; when precipitated from the atmosphere, it constitutes dew. This solution obeys the same laws with saline solutions; as has been shown by M. Le Roy of Montpellier, in an excellent memoir on the elevation and suspension of water in the atmosphere, (*Melanges de Physique et de Medicine, Paris, 1771.*)

7. One of the most remarkable phenomena of water in a vaporous state, is its power of quickening the combustion of oil; as in the experiment of the æolipile applied to the enameller's lamp, in common fires of mineral coal or charcoal, and in the burning of grease; instead of extinguishing, water rather increases the strength and fury of the flame in all these instances. These phenomena led Boerhaave to think that flame was in a great measure composed of water. We shall see how much this ingenious conjecture of Boerhaave's

have's is confirmed, or at least justified by the modern discoveries concerning water, when we come to show that this fluid, in a vaporous state, increases the violence of flame, in consequence of being itself decomposed by the bodies in combustion.

8. Water in vapour, and dissolved in the air, is condensed, and part of it precipitated, when exposed to a temperature a few degrees above the freezing point; it then resumes its liquidity; and in this manner is dew produced. Sometimes, when exposed to a sudden cold several degrees below the freezing point, it is congealed into icicles, and seems to suffer a kind of crystallization: hence those hoar, icy incrustations that are formed in winter on the windows of apartments exposed to the north: hence too those small icy flakes into which the aqueous vapours issuing from the lungs are formed in Siberia and other countries exposed to an extreme cold.

§ II. *Of the Chemical Properties of Water.*

No other natural body is susceptible of more combinations than water; and it has, on this account, long held the name of the *great solvent of nature*. The waters of the sea, of lakes, of rivers, springs, and fountains, are far from being pure, and are impregnated with almost every other substance, especially with saline matters.

It combines with air in two ways: 1. It absorbs this elastic fluid and retains it without passing from its liquid state. It even appears that water owes its pleasant fresh taste to the air thus combined with it. The pneu-

matic engine proves the reality of this combination; when the air above the water is exhausted, that which is mixed with it, is gradually disengaged in the form of bubbles. The air contained in water may be obtained by distilling the water in a pneumato-chemical apparatus. When water is boiled, the first bubbles that arise, consist of air, and the water, after losing them, has no longer the same lightness or relish. It recovers these properties by being exposed for some time to the open atmosphere, or by being briskly shaken. 2. Air, with a certain degree of heat, dissolves water, and renders it elastic and invisible like itself. The greater its heat, the greater also is its power of maintaining water in a state of solution. Le Roy of Montpellier has examined with minute attention the state of water in the atmosphere. His ingenious experiments show, that the driest hot air, if inclosed in a flask, and cooled to a certain temperature, affords a precipitate of water; that more or less aqueous vapour is necessary to saturate the same quantity of air according to its heat; and that this water is precipitated from the atmosphere through the night, and forms a particular kind of dew. He has even been led to think, from these facts, that the weight of the atmosphere depends upon the quantity it contains of this water, which is always in proportion to its temperature.

Though it be not consistent with the method which we propose to follow, to enter upon the examination of saline matters in this place; yet we must observe, that water, as it possesses in an high degree the property of dissolving them, always contains a certain

quantity of some saline substance. Calcareous salts are most frequently mixed with water, and communicate some disagreeable, and sometimes even noxious, qualities to well and river waters. These are sometimes also found to contain a portion of the carbonic acid, of clay, of iron, and of the extracts of vegetables altered by putrefaction. All such waters are unwholesome; those vitiated with the former mixture are called crude, hard waters: they have an insipid taste, are heavy upon the stomach, and unfavourable to digestion; and being likewise often purgative, the use of them is not without danger. It is, therefore, an object of considerable importance to distinguish the quality of water; to discover whether it be impregnated with any bodies which may communicate to it noxious properties; and to adopt means for purifying it from such a mixture.

Good wholesome water is generally distinguished by the following characteristics. It is very clear and limpid; no extraneous body alters its transparency; it has no smell; it has a lively, fresh, and almost pungent taste; it boils readily, and without losing its transparency; it entirely dissolves soap, in such a manner as to produce a homogeneous fluid, without clouds or lumps; it boils leguminous vegetables without hardening them: if tried by an addition of those liquors that are named *re-agents*, such as alkalis, and solutions of mercury and silver with nitre, it loses neither its purity nor transparency; or at least if it suffers any change of this kind, it is almost imperceptible. Lastly, it passes easily through the stomach and the intestines, and is favourable to digestion. Spring or river water, which filtrates or flows through sand, is in continual motion

and is not polluted with the putrefaction of animal or vegetable substances,—is found to possess all these properties: but filth must not be conveyed into it by sewers; the channel must not be filled up so as to divert or slacken its course; nor must hemp be steeped, or foul linens washed in it, &c. On the contrary, water which stagnates in subterraneous cavities, which issues from a calcareous or gypseous soil, which has no current, which is overgrown with plants or crawls with insects, which is very shallow, with a soft muddy bottom, consisting of putrid vegetables; all such water exhibits quite different qualities. Its taste is insipid or even nauseous; it has the smell of a mouldy or putrid substance; it is often green or yellowish; green or brown flakes of matter, the remains of putrefied vegetable substances, are seen swimming in it; it turns vegetable blues to green; it becomes dark and muddy when boiled; forms clouds with soap, and hardens all kinds of pulse; the re-agents cause it to give precipitates in greater or less abundance; it oppresses the stomach, remains long upon it, and retards digestion.

Several means are used to correct these bad qualities, which have been adopted entirely from the consideration of its physical and chemical properties.

1. Stagnant waters are put in motion by cutting out for them a sloping channel, exposing them to the action of mills, causing them to rise in spouts through the air, or to tumble down in cascades. By these means the putrid gas and spiritus rector are made to evaporate, extraneous matters are collected and deposited in the bottom, and a considerable quantity of air is attracted into combination with the water.

2. Marshes and pools are cleansed of all putrefying animal and vegetable substances: and this cannot be done without agitating their waters at the same time, which is also serviceable.

3. Water is filtrated through jars or fountains, the bottoms of which are covered with fine sand and sponges: these need to be renewed from time to time. The bottoms of small rivulets naturally covered with a bed of mud, are also laid with sand and pebbles.

4. The above are means for purifying water by separating from it such heterogeneous matter as may happen to float in it; but they cannot deprive it of any saline substances that exist in it in a state of solution. To separate these from water, it must be boiled, left to settle and cool till it become clear, then filtrated through paper or pure sand, and exposed to the air in broad stone vessels. After undergoing this process, it may be drunk with safety. Ebullition frees hard water of the principle which occasions its disagreeable smell, and causes it to precipitate part of its calcareous salts: but to produce the last effect, the water must be boiled for half an hour, or for so long time as may be necessary to make it dissolve soap, and to deprive it of the property of hardening pulse.

5. If boiling be found insufficient for purifying water of its calcareous salts, as sometimes happens when it is strongly impregnated; these must then be precipitated by boiling it with a small quantity of potashes, or for want of potashes with common ashes; the salts then fall to the bottom; and the water being suffered to settle, and exposed to the air, acquires all the qualities which we wish it to possess.

6. We may also make use of some substances to correct the disagreeable and noxious qualities of water, such as sugar, meal, barley, corn, honey, pot-herbs, and some labiated aromatic plants. But these cannot, like the former means, communicate to it the qualities of pure water; they only substitute one taste in the place of another.

This account of the chemical properties of water represents it only as a powerful agent in combination, capable of entering into union with many natural bodies. But in many of its combinations it suffers a remarkable alteration, which was not taken notice of till the month of April 1784; and which is highly worthy of the attention of chemists.

Water has long been known to favour combustion in some instances, as in the enameller's lamp, in the inflammation of oils, in strong conflagrations, &c. Some philosophers had thought themselves authorized by these facts to conclude, that water was sometimes changed into air: but we are indebted to a few French academicians for a more accurate account of these phenomena, and of the nature of water. M. Lavoisier having observed, with M. De la Place, that when inflammable gas is burnt in a close vessel, by the help of vital air, a product of pure water is obtained (a fact which was observed almost at the same time by M. Monge, with the most accurate attention, in the laboratory of the school of Meziere), concluded, that this product must be composed by the combination of vital air with inflammable gas; and that these were the constituent principles of water. This theory, by which M. Lavoisier presumed to deprive water all at once, of the character

character of a simple elementary body, which it had so long maintained, met with keen opposition ; and its author found himself under a necessity of establishing it by analytical as well as by synthetic facts. He therefore attempted to decompose this fluid, by exhibiting to it bodies, the affinity of which with one of its principles was so strong, that they might be expected to separate it from the other. Obtaining the assistance of M. Meusnier, in his researches on this head, those two philosophers read, in the academy, on the 21st of April 1784, a Memoir, proving that water is not a simple substance, but a genuine compound of the base of inflammable gas with that of vital air or the oxygenous principle ; and that the two principles may be easily separated from each other. To obtain these two matters separate, M. Lavoisier at first employed the following process. In a small bell-glass, above so much mercury, he put a certain quantity of very pure distilled water mixed with iron filings : These filings were gradually calcined ; an inflammable elastic fluid was disengaged, and collected immediately above the mercury ; and in proportion as these two phenomena appeared, the quantity of the water was diminished. By prosecuting this experiment farther, the iron may be entirely calcined and totally decomposed ; for the water, in M. Lavoisier's opinion, both occasions the calcination of the iron and gives out the inflammable gas. As the fluid is composed of the oxygenous principle and the base of inflammable gas, the iron gradually depriving it of the former, combines with that principle to form a metallic oxide, and leaves the inflammable gas disengaged. Such was the first experiment in which

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this enlightened chemist accomplished the decomposition of water. But in those researches which he prosecuted in conjunction with M. Meusnier, he followed a much shorter and more conclusive process. Placing the barrel of a gun in a furnace, and heating it red-hot, he dropped a certain quantity of water through it. In this process, the water being reduced to vapour is decomposed as soon as it comes into contact with the red iron, and the oxigene which it contains becomes fixed in the metal ; as appears from the increase of its weight and the alteration of its substance. The base of inflammable gas being set at liberty, passes quickly through the gun-barrel, and is received into bell-glasses placed for that purpose at the opposite end. On a repetition of their experiments, with all the precision possible, those philosophers discovered, that water contains about six parts of the oxigenous principle with one of the base of inflammable gas ; that of consequence this last principle constitutes but a seventh part of the compound ; that it is thirteen times lighter than common air ; and that it occupies, when at liberty, fifteen hundred times the space which it filled in its aqueous combination.

Water appears to act in the same manner on many other combustible bodies, which it reduces with more or less facility to a burnt state, and to afford uniformly a quantity of inflammable gas. It may be decomposed with zinc, charcoal, or oils ; with the last of these, by dropping the water into boiling oil in a retort, the neck of which is immersed under the glasses of a common pneumato-chemical machine. But great caution is necessary to prevent the explosion that takes place when the water rises in the vacuum produced in
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the neck of the retort by the ebullition of the oil. To determine certainly whether a combustible body, such as a metal, a coal, &c. be capable of decomposing water, immerse a piece of it red hot into a vessel of water, under a bell-glass filled with the same fluid, and the inflammable gas, which is always disengaged whenever water is decomposed, will be received into the glass. These, namely, the decomposition of water, and the production of inflammable gas, are the reasons why bubbles arise when red iron is plunged into water, as has been observed by Messrs Haffenraff, Stouttz, and D'Hellancourt, of the royal mineralogical school of France. A similar disengagement of inflammable gas, the consequence of the decomposition of water, takes place when a piece of flaming charcoal is thrown into a quantity of this fluid.

These are the newly discovered facts concerning the nature and composition of water. Messrs Lavoisier and Meusnier think, therefore, that this fluid is a compound of about six parts of the oxygenous principle and one of the base of inflammable gas, or, more accurately, of 0.86 of the former body, and 0.14 of the latter; that iron, charcoal, and oils, having a stronger affinity with the oxygenous principle than it has with the base of inflammable gas, enter into combination with it, leave the combustible elastic fluid disengaged, and thus decompose water; that this liquid may be again formed by burning inflammable gas with vital air; that when this process of combustion is carefully performed, a quantity of water is obtained, which answers precisely in weight to the quantity of the two gases, by
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the combination of which it was produced ; that in many chemical operations, water is produced by this combination ; and that, therefore, if spirit of wine and oils be burnt under a chimney, proper for condensing their vapours, and fitted to the worm-pipe of a still, the other end of which is joined to a receiver, a quantity of water will be obtained almost always greater than that of the combustible liquid which affords it ; because the inflammable gas, disengaged from the liquid, combines with the pure part of the atmospheric air which is decomposed during the combustion.

These discoveries, and the theory founded upon them, cannot but form one of the most illustrious æras in the history of natural philosophy. As it is of the utmost importance to consider all the consequences of which it admits, with all possible care, we shall here add a few observations, in order to convey more distinct and accurate ideas of it.

We have mentioned, that all aëriform fluids owe their gaseous state to the matter of fire or heat combined with them. Inflammable gas depends on the same principle : For as the decomposition of water and its change into inflammable gas always require an high temperature, and as the more violent the heat applied, the more rapid is the change ; this gas, therefore, appears to acquire its amazing levity, and to assume the aëriform state, in consequence of a considerable quantity of heat being absorbed by its aqueous base ; which is the reason why it can never be obtained but in a state of extreme fusion. It becomes, therefore, necessary to bestow a particular name on this base of inflammable
gas,

gas, which when combined with the oxigenous principle, the base of vital air, is susceptible of a solid form, as in the instance of ice. This base being considered as one of the essential principles of water, must be distinguished by a name expressive of that property. We have adopted the word *hydrogene*, or *hydrogenous* principle, as answering the purpose. And we call water a compound of the oxigenous principle, or the base of vital air, and the hydrogenous principle, or the base of inflammable gas. And as there are many inflammable elastic fluids, such as alcohol, æther, volatile oils, &c. when reduced to elastic fluidity; we distinguish this principle of water in its aëriform state by the name of *hydrogenous gas*.

In a future chapter we shall have occasion to review this important subject; in this place it is sufficient to have shown, that water is not a simple, but a decomposable body. Nature in her grand operations effects the separation of principles with much greater facility than art, and by many more ways than art can ever discover or adopt. It is in consequence of its decomposition that water purifies the atmosphere, by pouring into it streams of vital air; that it contributes to the formation of saline matters, of the principles of which pure air is always one; and that such a quantity of inflammable gas is often disengaged from stagnant waters, as sometimes to overload the atmosphere, and to produce igneous meteors, in consequence of being kindled by the electric fluid in its struggles to maintain its equilibrium. Lastly, This fine discovery of the compo-

nent principles of water, its decomposition and re-composition, illustrates and explains many of the phenomena of nature, particularly the renovation of the atmosphere, the solution of metals, vegetation fermentation, and putrefaction ; as shall be shown more at large in several succeeding chapters of this work.

C H A P.

C H A P. VIII.

Of Earth in general.

Philosophers of antiquity believed in the existence of a simple substance, the principle of solids, gravity, dryness, and fixity, and the base of all bodies, to which they gave the name of *earth*. This opinion, founded solely on abstract reasoning and analysis, has long been taught in the schools, and is maintained by a number of philosophers. Paracelsus gave the name of earth to all residues obtained by analysis. But succeeding chemists following the example of Glauber, to examine residues with as much care as products, were soon convinced that those were far from being pure earth; and the opinion of Paracelsus was of consequence exploded. Boerhaave having adopted the notion of Paracelsus under some reservations, observed, that after every analysis, there remained a dry, insipid, heavy, colourless matter; possessing in short all the properties of earth. But these, when chemically examined, are found to differ considerably from one another, that they cannot, by propriety, be comprehended under one denomination.

Boerhaave, as has been already mentioned in our account of principles, admitted three different kinds of earth; vitreous, inflammable, and mercurial. Stahl considered the first of these as the only genuine earth: and

Macquer follows Stahl in thinking vitrifiable earth the purest and the most elementary.

In order to determine what judgement we ought to form on this matter, let us first examine attentively the properties which chemists agree in ascribing to elementary earth. We find six which have been considered as its distinguishing characteristics; namely, gravity, hardness, insipidity, fixity, infusibility, and inalterability. But all of these properties are found as well in the earth which forms the base of rock-crystal, quartz, and vitrifiable stones in general, as in clays. If then a number of substances, considerably different from one another in many respects, be found to possess in common all the distinctive properties attributed to elementary earth, are we to consider them as so many simple primary earths? Or, shall we rather adopt the opinion of Stahl and Macquer, who, finding vitrifiable earth to possess in a more eminent degree all the properties of elementary earth, consider it as the only genuine primary earth, and the others merely as bodies formed by it in combination with different principles?

However plausible this opinion, however respectable its authors, we cannot agree to consider vitrifiable earth as the only primary and elementary earth: 1. Because this earth is not found in equal purity, even in all the stones in which Stahl and Macquer have themselves admitted its existence; for instance, let quartz, rock-crystal, and flints, be examined and compared. 2. Because all the discriminating properties of earth are found to belong to many substances which differ from vitrifiable earths only in possessing those characteristics in a less eminent degree. 3. Because vitrifiable earth has
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not been hitherto shown to be, as some chemists think it, the base of all solid matters, and of all the various kinds of earth.

We must adopt the following sentiments with regard to this matter. We observe many substances in nature possessing the properties of earths; among which it is impossible to distinguish which is the most simple, as chemists find them all to possess nearly the same degree of simplicity: Besides, though one of these should be demonstrated to be more simple than the rest, it would be farther necessary to show that it enters into their composition, and constitutes the principle of their coherence and solidity. Wherefore, without presuming to determine what is properly elementary earth, we ought to admit the existence of various kinds of earths, and to study their properties, in order that we may recognise and distinguish them whenever chemical analysis offers any of them to our attention, combined or separate.

Chemists have long allowed the existence of several kinds of earthy matters: but the earlier classifications of these matters are faulty, because the properties assumed as characteristics were neither sufficiently numerous nor such as the substances were certainly known to possess. Such, for instance, is the division of earths into mineral, vegetable, and animal: for though the fixed residues obtained by a last analysis of organized matters, after lixiviating their ashes, be generally destitute of taste or smell, dry and indissoluble, yet these properties are not sufficient to entitle them to a place among the earths, as they possess neither inalterability, infusibility, nor simplicity. That substance which

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composes

composes the dry, solid base of animal bones, and which, from its dryness, insipidity, and insolubility, had obtained the name of earth, has been, within these few years, discovered to be a true saline matter; as we shall show at large in the chemical history of the animal kingdom. And we may with great probability conjecture, that the insipid, insoluble parts, which remain after the last analysis of other animal matters, are of the same nature. The name metallic earth, given to the calces of metals from their dryness, and because some of them are destitute of smell and incapable of solution, does not properly belong to them; for they are extremely fusible, and are, every one of them, compounds, as shall be afterwards shown.

The mineralogists who have treated of the history of earths, have formed a more regular and accurate arrangement of them than chemists, who have considered this subject only in general, so far as it is connected with the theory of chemistry. Most of the modern philosophers who have attempted a classification of these matters, have characterized them by their chemical properties, and have by that means thrown much new light on the natural history of the mineral kingdom. Wallerius, Cronstedt, and Monnet, have given complete systems of mineralogy on this plan. No chemist has made more numerous experiments on earths and stones than Pott, who has given a methodical arrangement of those bodies according to his own observations. The continual labours of M. D'Arcet, and the many analyses of stones made by Bergman and Bayen, likewise merit the highest praise. We shall not attempt to exhibit and compare the several classifications

ications of these philosophers : our present object is not to detail the natural history of earthy matters, but merely to give the results of the various researches which have been directed to this purpose, with a view to show how many kinds there are of earth considered chemically, and what are the characteristic properties of each kind.

Before proceeding farther, we must observe, that in our opinion no distinction should be made between earths and stones as to classification ; because, when we consider them chemically, their substance is the same, and only their aggregation different. Grit-stone, for instance, is but sand agglomerated by the force of aggregation ; and sand is nothing but grit-stone, the integrant parts of which are divided, and their aggregation broken : the same chemical properties are common to both.

Pott has divided earths and stones into four classes ; the vitrifiable, the argillaceous, the calcareous, and the gypseous. From later discoveries it appears, that the substances hitherto known by the name of calcareous earths, are true neutral salts : gypseous stones have been likewise discovered to be a kind of saline substance. Only two, therefore, of Pott's four classes of stones actually belong to this division of natural bodies. Dr Black, whose name will long mark one of the most illustrious æras in the annals of modern chemistry, by examining the base of Epsom salt, has discovered it to consist of a peculiar substance, to which he has given the name of magnesia, and classed it among the earths. And his opinion has been unanimously adopted by chemists. Bergman, in analysing ponderous spar, has

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discovered

discovered a peculiar earth, to which he has given the name of *terra ponderosa*, and which we call *barytes*.

We think these two last substances ought to be distinguished from earths properly so called, for reasons to be mentioned in the following chapters.

Thus we acknowledge as true earths none but such matters as are absolutely insipid, insoluble and infusible; and we distinguish, by a chemical examination, what substances possess these properties. We admit only two kinds of pure earth, equally simple and equally elementary.

The first is that which constitutes the base of rock-crystal, quartz, grit-stone, flints, and of almost all hard-scintillating stones. Its chemical character is to suffer no alteration even from the most violent action of fire, but to retain its hardness, transparency, and all its other properties, to whatever degree of heat it be exposed. It has been called *vitriifiable earth*, because it is the only species of earth capable of forming, in combination with alkalies, transparent glass. But the name which we prefer is *silice*, derived from that of siliceous earth, which has been likewise given it because it is constantly found in silices.

The second kind of earth which we consider as simple and pure, is pure argillaceous or *aluminous* earth. The following properties considerably different from those of the former species, form its peculiar character. However pure, it is almost always opaque; or if it enter into any transparent stones, these are much inferior in transparency to siliceous stones. It is always disposed

disposed in thin layers or laminæ, one above another. This disposition corresponds to the crystalline form which the former species constantly affects. Though it have no stronger taste than siliceous earth, yet it appears to act in some manner on our organs ; for it adheres to the tongue : which property naturalists express by saying, that *it sticks to the tongue*. Its force of aggregation is never so strong as that of the former earth ; for which reason argillaceous stones are never very hard, but may be broken by a blow with a hammer, without being cut or struck till they gave fire, like scintillating stones. The aggregative force of aluminous earth being so weak, renders it much more susceptible of combination than the other kinds ; and accordingly clays are much seldomer found pure than either quartz or rock-crystal. From this it may be easily inferred, why clays are almost always coloured, and why few of them possess all the properties of the aluminous character in any eminent degree. Aluminous earth suffers an alteration from the action of heat, to which siliceous earth is not liable. Instead of remaining, like the latter, unchanged when exposed to an ardent heat, it acquires an addition of aggregative force. It even assumes, in such circumstances, some of the properties of the siliceous earth, its hardness and aversion to combination. Water acts on aluminous earth, penetrates into its substance, adheres to it, and renders it soft and ductile. The existence of this combination appears from the difficulty with which the adhesion between these two substances is overcome, a strong and long continued heat being necessary to effect a separation.

tion between them. The properties which this species of earth possess of composing a paste with water, and becoming hard by the action of fire, render it a very valuable material in the arts. Lastly, another property of aluminous earth, which distinguishes it from the siliceous still more than any of the former, is its capacity of entering into combination with a vast number of other bodies. So subject is aluminous earth to the affinity of composition, that we find it a principle in many compounds: and for this reason we have enumerated and described its properties more at large, in order that it may be readily recognised when obtained in analyses.

These are the two kinds of earthy matter which appear worthy of being considered as distinct classes, and likewise as elementary substances, since they have not hitherto been decomposed. We are not sufficiently acquainted with their origin, their formation and their chemical properties, to pronounce as some chemists have ventured to do, that one of them is simpler than the other, and that the other is nothing but a modification of it. We cannot think ourselves as yet authorised to advance, that the earth of rock-crystal, or siliceous earth, is the base of the aluminous, to constitute which it only needs to be attenuated, divided, and wrought up in a particular manner; because no chemist has hitherto accomplished such a transmutation.

The two earthy matters, of the properties of which we have here taken a general view, are seldom found pure. Rock-crystal is the only body which affords siliceous earth in this state; doubtless because it is excessively hard, and possesses the force of aggregation in

an high degree. Even there, it is often coloured by the addition of some extraneous substance. In quartz it is still oftener altered by combination with some colouring matters. But aluminous earth is still seldomer found pure. In short, almost all the earths and stones which naturalists have distinguished by different names, are compounds of one or two simple earths, or of saline earthy substances, particularly of chalk and magnesia, and sometimes of metallic matters, of which iron occurs the most frequently. To be convinced of this, the reader needs only to cast his eyes on M. Monnet's work, in which he has arranged stones according to their constituent parts. That chemist's plan of arrangement certainly merits no small praise; but while it exhibits to view all the advantages which lithology can derive from chemistry, it at the same time shows how far we are from an accurate and certain classification of stones according to their chemical properties. This subject falls under our discussion in the following chapters.

P A R T.

PART SECOND.

The MINERAL KINGDOM: MINERALOGY.

SECTION I.

EARTHS *and* STONES.

CHAP. I.

General View of Mineralogy: General Division of Minerals, and particular Division of Earths and Stones; their various Characteristics.

ALL the bodies of the globe which we inhabit are the objects of natural history. So grand and sublime is this science, when considered with a view to its general scope! so extensive, when traced through all the minute details into which it enters! Its observation ranges from the meteorous phenomena of the atmosphere to the changes which the matters deposited in the strata of our earth undergo. All the bodies scattered over its surface, seas, lakes, rivers, brooks, mountains, hills, valleys, plains, and caverns, engage the attention of him who cultivates natural history. The inanimate matter of the globe,

animals inhabiting it, are equally the subjects of his curious inquiry. The eye of genius may indeed comprehend the whole under one grand and extensive view: but humble scrupulous observation confines itself to minute detail; detaches the several parts of this great whole; examines them apart from one another; and thus divides the science into a number of separate branches. Many a man of invincible perseverance, has spent his life in observing and describing the manners and operations of insects; and yet the subject is not exhausted.

The student might therefore be deterred from the study of natural history as too arduous and disgusting a task; but those who have successfully prosecuted the science, have endeavoured to smoothe the difficulties of the road to its attainment, by adopting means for rendering it easier of comprehension, and for assisting the memory. These are called *methods*. They consist in arrangements of natural bodies, according to their properties. The characteristics on which such a classification is founded ought to be striking and invariable.

One of the most distinct and important is a division of all natural bodies into three great orders, which are named *kingdoms*; the mineral, the vegetable, and the animal. Though the two last of these seem to possess some leading properties in common, yet the difference between them in point of form and exterior organization is sufficient to make us consider them as separate orders.

Minerals compose the solid mass of the globe, or at least its exterior crust through which the efforts of men have penetrated. are in-

creased only by the juxta-position of their parts and by their attractive force. They are liable to no change or variation, but such as are occasioned by the mutual chemical action of bodies. And for these reasons they are named *rude, inorganized, inanimate bodies*.

Vegetables, again, increase by the operation of an interior power: they have organs to refine and convert into nourishment, the juices which they derive from the earth and the atmosphere. They spring up, live, and die; by a real generation, they propagate other bodies like themselves.

Lastly, Animals have organs more complex than those of vegetables; undergo more rapid changes; and are, from their superior sensibility and loco-motive powers, much more subject to the influence of surrounding bodies.

The branch of natural history which comprehends the description of minerals, is named *mineralogy*. The first naturalists who attempted classification, arranged minerals into a great many classes. They admitted into their arrangements, as so many distinct orders of minerals, water, earth, sand, soft stones, hard stones, precious stones, figured stones, salts, sulphur, pyrites, minerals properly so called, and metals, &c. Concerning the progress that mineralogy has made since the days of Henckel, one of the first who wrote in a methodical manner on this department of natural history, till the appearance of M. Daubenton, whose classification is a master-piece of accuracy and precision, the reader may consult the systems published during that period; of which a collection has been made by M. Monn

nior*. He traces the successive improvements which the science has received from the labours of Bromel, Cramer, Henckel, Woltersdorff, Gellert, Cartheuser, Justi, Lehman, Wallerius, Linnæus, Vogel, Scopoli, Romé de Lille, Cronstedt, De Borne, Monnet, Bergman, Sage; concluding with those of M. Daubenton, who has accomplished all that could be wished.

To make ourselves acquainted with minerals, the first thing to be done is, to distinguish them into so many classes marked, each by some leading and distinct properties. We shall accordingly divide them into three. Under the first, we shall arrange those stones and earths which are insipid, insoluble, and incombustible: under the second, saline matters, having a stronger or fainter taste, soluble in water, but incombustible: and, under the third, combustible substances insoluble in water, and affording either a weaker or stronger flame when exposed to the contact of fire, and at the same time not excluded from the access of air.

Most of that part of the mass of our globe with which we are acquainted consists of earths and stones, which by their insipidity, insolubility, and incombustibility, are distinguished from salts and inflammable bodies. Being regularly arranged in strata or layers, they form mountains, hills, and plains; in mountains, they are disposed either in huge shapeless masses, or in inclined horizontal layers; in plains, they are ranged in horizontal strata, and covered with a bed of vegetative earth, produced by the accumulation of the remains of organized bodies. Often, however, such large masses appear under a regular crystalline form in subterraneous cavities

or

or clefts. Most of them appear to have been formed by the action of water; and it is continually dividing, attenuating, and transporting them from one place to another, and causing them to undergo many other changes. The natural history of these bodies constitutes *geology* and *lithology*; the first treating of earths, the second of stones: But the two should be united under one class; for all earths, excepting mould formed of the residues of putrefied organized substances, are nothing but stones, the aggregation of which is destroyed; and stones again are formed by the union of earthy matters.

As there are a vast number of different kinds of earths and stones, and a knowledge of them is highly important in science, as well as of great use in the arts of life; philosophers have sought to distinguish them from one another, and to give certain directions for recognizing them wherever they occur. Ancient naturalists did not think of dividing them into distinct classes by their peculiar properties; they were content with describing their general qualities, and followed the order of their real utility or fancied value. Few of the stones, therefore, mentioned by Pliny in his natural history, can now be found. Modern naturalists, observing the inconveniencies which attend this way of describing stones, have adopted a different method, in order to establish more obvious and lasting distinctions. By observing their exterior and sensible properties, they have arranged them into orders, genera, and species; and have thus rendered the study more easy and advantageous.

Form, hardness, interior structure, colour, and the appearance they exhibit when broken, are the properties

ties which have been assumed as characteristics of earths and stones. To these some naturalists have added some of their chemical properties, especially the manner in which they are affected by fire, and the alterations which they suffer from acids. Let us here examine each of these properties, in order to understand the application of the general principles of lithology to the particular history of each of the genera of stones.

§ I. *Form considered as a Characteristic of Stones.*

By the form of Stones, we understand the order and relative arrangement of their surfaces. The eye, at the very first glance on a collection of stones in a cabinet, perceives some of them to be of a regular geometrical figure, and others irregular masses; and observes, that regularity of form is in some instances accompanied with transparency, in some with opacity. Uniform observation has established it as a certain fact, that some species of stones always follow a particular mode of crystallization; while others never appear but in irregular fragments. Several naturalists are of opinion, that all stony matters possess the property of assuming a crystalline form; that some indeed possess it in a higher degree, and display it more invariably than others, but that all have some peculiar crystalline form, which appears in their minutest particles. Such is the opinion of M. Romé de Lille, who has given a very curious and accurate history of the various crystallizations of mineral substances*. That philosopher arranges the forms in which stones and all other mineral bodies ap-

* Voyez la *Cristallographie*, 2d edit. Paris 1783.

pear, under the three denominations of determinate, indeterminate, and confused crystallization ; and shows that there is no mineral substance but appears in one or other of these states. But the truth is, so many of them affect the second mode of crystallization, and the third which is irregular and difficult to be distinguished, that we cannot gain a sufficient knowledge of the crystalline form of stones, to authorize us to assume this as one of their determinate characteristics. Yet a number of mineralogists have formed general systems of lithology and mineralogy on the principle of the regularity of the form of stones and minerals. Linnæus was the first that adopted this plan of classification ; and though he has not entirely accomplished what he proposed in introducing it, he at least directed the attention of succeeding naturalists to this property of stones, and opened the way that has led to all the discoveries which have since been made on this subject.

Such is the state of the present opinions concerning the connection between crystallography and the study of stones and minerals. It explains the formation, and sometimes the nature of these substances ; and often helps us to recognize and distinguish them from one another : but it is not adequate to form the basis of a complete system of mineralogy ; it is only one of the means to be employed in a classification of minerals. That eminent philosopher M. Romé de Lille, to whose labours we are indebted for so much of our knowledge concerning the peculiar forms of minerals, has not founded his divisions of these bodies on their crystallization alone ; instead of making this form the great principle of his classification, he has only examined and
described

ibed the forms of mineral substances, classed according as their nature is saline, stony, or metallic, and adding to the various combinations into which they

Hardness considered as a Characteristic of Stones.

There are a great many varieties of the aggregation of the component particles of stones, of which linguists have happily availed themselves to distinguish them from one another. Some have such strength of aggregation, and such a degree of hardness, that they yield not even to the best tempered steel, such as diamonds or precious stones. Others yield, and may be cut with instruments, but not without difficulty, such as quartz, flints, hard grit-stone, porphyry, and granite.

All of these stones when struck smartly against a steel blade produce a great many sparks; which property has gained them the name of *scintillating* or *igneous stones*. Those sparks are minute pieces broken off from the steel by its collision with the stones, and kindled by the heat which that collision produces: that heat is even so intense, that the particles struck off from the steel are melted; and if they be collected on a piece of white paper, and viewed through a magnifier, will appear a parcel of half-calcined, half-vitrified matter, like the drops of forges. As the stones which are struck in this manner on steel are not all of the same density, but vary from the hardness of gems and rock-crystal to the softness of sand-stones and vitrifiable breccias recently formed, they must afford a greater or a

smaller quantity of sparks, according to their respective degrees of hardness.

There are a great many other stones, the aggregative force of which is much less considerable, and which are so soft that they may be easily cut with steel instruments. Some of them, such as marble and alabaster, are susceptible of a fine uniform polish. The rest, and among these almost all argillaceous stones, admit only of an imperfect polish, and always retain a dull, greasy appearance. We can at any time judge of the hardness of those which possess this property in so moderate a degree, and of the polish of which they are susceptible, by wetting their surface. This simple process communicates to them a momentary polish, which disappears in proportion as the moisture evaporates.

It is to be observed, that many other stones beside the class of ignescents produce a real scintillation when struck against steel; the reason of which is, that such stones are mixtures, containing some ignescent parts. Thus, some kinds of marble, and many calcareous breccias, scintillate when struck against steel; because they contain quartzose or flinty particles, intermixed with the calcareous matter of which they are mostly composed.

The gravity of stones is necessarily proportioned to their density. Some naturalists have considered this property as of great importance in a classification of stony matters. M. de Buffon considers specific gravity as one of the best means to enable us to distinguish their particular character. But such nice and accurate experiments are necessary to determine the relative gravities of stones, that this property cannot very well be
assumed

assumed as the basis of a lithologic method ; as plainness and simplicity are highly requisite in the elements of this branch of natural history.

§ III. *Of the Fracture, Considered as a Characteristic of Stones.*

ALL stones when broken display a certain arrangement of their integrant parts, an interior contexture and disposition of their particles : but this, so far from being uniformly the same, is infinitely diversified through the various classes of stony substances. To this appearance which stones present when broken, lithologists have given the name of *fracture*. By observing it, we may learn some particulars which will be of use to help us to distinguish their peculiar characters. From a comparison of such observations as have been made on the interior structure of stones, it appears that the several sorts of fracture which they afford may be reduced under certain heads. Some, like glass, give smooth polished surfaces of a curved figure. This is denominated the *vitreous fracture* ; it appears very distinctly in rock-crystal, quartz, &c.

Others again display surfaces, which are uniformly smooth, but in their figure alternately convex and concave. The pieces may be neatly re-united. This is called the *conchoidal fracture*. The corresponding convexity and concavity are of various forms and sizes, wide, narrow, round, oblong, deep, shallow, &c. ; as in several kinds of flint, jasper, agate, and petrosilex.

There is another kind of stones, which when broken exhibit on their new surfaces an assemblage of round

projecting points, similar to grains of sand worn by water: this is called the *granulated fracture*, and is very observable in sand-stone. The size and other varieties of the granulation constitute a number of distinctions among the stones of this species, serving to diversify their characters. It is of this species we speak when we say *fine* or *coarse grained* stones.

Lastly, There are many stones, the fracture of which shows them to consist of smooth equal laminæ, disposed one over another. Most of these are stones which bear the name of *spars*; and this is therefore denominated *the sparry fracture*. These laminæ differ from one another in extent, magnitude, thickness, transparency, and position with regard to the axis of the crystallized stone; for all the brilliant stones of this fracture exhibit a real crystallization. Such as are dark and without lustre, are only said to be *lamellated*, not sparry. The disposition of the laminæ, so much diversified in gems, and calcareous, vitreous, and ponderous spars, is what occasions the brilliancy of talc, and the several kinds of feldt-spar, such as cat's eye, the aventurine, the labradore stone, &c.

Some writers on this subject have arranged stones according to their fracture, considered in conjunction with their general form. In the year 1755, Cartheuser published a system of mineralogy, in which he distinguishes stones into lamellated, fibrous, solid, and granulated. But fracture alone is insufficient for the principle of a classification of stones; it must be taken together with the other characteristics which are examined in this chapter *.

§ IV.

* See *L'Introduction a la Sciagraphie de Bergman*, par M. Monge le Jeune, page 21.—F.

§ IV. *Colour considered as a Characteristic of Stones.*

THAT diversity of colours which we observe in stones, is occasioned by the various combustible or metallic substances which enter into their composition. Sometimes the whole stone is of the same colour, and sometimes variegated. The colouring part of stones is generally an accidental property of their nature ; the presence of which is not absolutely necessary, and which is liable to great varieties. There are indeed some kinds of stones which are pretty uniformly coloured, such as crystallized gems, schorls, and tourmalines ; and in these the colour may be assumed as a characteristic. But as there are other species, and more especially varieties, of which it cannot be considered as a distinguishing property, lithologists therefore do not refer to it as a principle of classification.

Where colour may be considered as a characteristic property, we must distinguish between such stones as are all of one colour, and uniformly opaque, or uniformly transparent, and such as are variegated with specks or veins ; we must likewise take notice of the number of the colours which appear in any mass of stone ; as in marble, for instance, there are sometimes no fewer than six or seven. According to the number and the disposition of the colours in those bodies, they are distinguished into stones of one, two, three, or four colours, variegated, spotted, veined, punctuated, clouded, flowered, figured, herborised, &c.

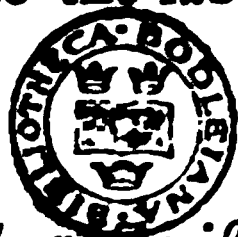
§ V. *Alteration produced by Fire, considered as a Characteristic of Stones.*

SEVERAL mineralogists, not content with observing the exterior and more observable qualities of stones, have extended their inquiries to their chemical properties, with a view to assume these as grounds of distinction. The particular alteration which any stone suffers from the action of fire, is considered by many lithologists as an excellent mean for enabling us to ascertain its peculiar nature. They have observed, that fire deprives some stones, such as quartz, of their transparency and hardness, without changing their nature or altering their essential properties: others again, such as rock-crystal, have been found to lose not even their density and transparency when exposed to the action of heat: and others have been found fusible and transmutable into glass of various colours; of which kind are schorls, zeolites, asbestos, amianthus, and granites: lastly, there are still many others, such as calcareous stones, which fire deprives of part of their weight, destroying their consistency, and rendering them soluble in water, without melting them. Other experiments, managed with more careful attention, have shown, that some stones lose their colour by fire, and that to some it communicates a deeper shade. Such in general is the result of the experiments of Messrs Pott, D'Arcet, and many other chemists.

To complete the natural history of stones, it is necessary to take notice of these alterations, and to mark their differences. It appears in general, that simple
stones

ones are liable to the least alteration of their properties by fire: and that in proportion as a stone is more or less compound, it is more or less subject to such an alteration. But still the observation of these alterations cannot be of much benefit to lithologists, as the experiments necessary to discover them are tedious and difficult; whereas the properties assumed as characteristics in a classification of stones, should be such as are obvious to the eye, or at least may be discovered by a simple expeditious process.

Sometimes, indeed, when we cannot determine the nature of a stone by observing its external properties, we may have recourse to the alteration which it suffers from the action of fire, by means of the blow-pipe, an ingenious contrivance of Bergman's. Yet notwithstanding the ingenious simplicity of this invention, the necessary apparatus is so incommodious, that it can scarce be rendered portable, so as to be used in a lithologic excursion, but must remain confined to the laboratory*.



VI. *The Action of Acids considered as a Characteristic of Stones.*

ACIDS are the solvents ofteneft used in chemistry.
Though

* See Bergman on the blow-pipe, at the end of his *Chemical Essays*, translated into English by Dr E. Cullen. London 1784.

All the apparatus necessary is a blow-pipe, a piece of charcoal, a small silver spoon, and three small phials containing soda, fusible salt, and borax; and the process may be performed in any place where a candle can be sheltered from the wind. Complete apparatus for the purpose, in a box no larger than a book in twelve, are sold at a Mr Brown's, bookseller, near the Strand, London.—I

Though we have not yet treated of these salts, yet we must here say a few words of the phenomena which stones exhibit when brought into contact with them. The greater part suffer no alteration from acid salts; but some display a very observable motion, and an agitation somewhat like a slight ebullition, if a drop of the nitric acid be caused to fall through a glass-tube on their surface. This phenomena bears the name of *effervescence*. It is owing to an aëriform substance, which being disengaged from the stone by the action of the acid, rises through the acid in a number of small bubbles. That elastic fluid is itself a peculiar acid, disengaged by the more active acid poured on the stone, and is the product of an actual decomposition. All calcareous stones exhibit this effervescence when brought into contact with acids: the nitric acid produces the most powerful effects, and is most commonly employed on such occasions. The disengagement of an aëriform acid is a proof that the matter from which it issues is a saline combination: But as this combination is insoluble, and without any discernible taste, and as it composes most of the exterior layers of the globe of the earth, naturalists always consider it as a stony substance.

Stones may therefore be divided into effervescent and non-effervescent. And a small phial full of nitric acid becomes of consequence a necessary article in excursions to examine and collect stones. This, together with the magnifier and the steel, are all the instruments which the lithologist needs to carry with him on such an expedition.

Since Bergman recommended the examination of stones by fire with the blow-pipe, they are also assayed
with

with soda, borax, and fusible salt, which act variously upon them according to the differences of their nature, but generally produce fusion in some degree, together with other phenomena. We shall explain this method of analysing stones more particularly in the chapter in which we treat of all the methods of effecting that analysis.

C H A P.

C H A P. II.

The Lithologic Method of M. Daubenton, extracted from his Tableau de Mineralogie.

NONE of all the mineralogists who have attempted a methodical arrangement of stones, has given a more accurate or perspicuous classification than M. Daubenton. The ingenuity with which this naturalist, so deservedly celebrated, has contrasted the characteristics of those substances, renders his method more accurate and useful than any before proposed. The properties which he has assumed as characteristics are all invariable and obvious. They are chiefly regularity or irregularity of form; the various degrees of transparency and opacity; consistency or hardness; the polish of which stones are susceptible; the form or respective arrangement of the integrant parts, which occasions the vitreous, conchoidal, granulated, lamellated, and spathose fractures; colours, in those instances in which they are not accidental; a dusky, brilliant, or mildly lucid surface. As it would be impossible to improve upon the perspicuity and accuracy of M. Daubenton's system, all that we shall here do, is, to lay before our readers his division of earths and stones, as he has exhibited it in his *Tableau Methodique de Mineraux**.

F I R S T

* *Tableau Methodique des Mineraux, suivant leurs differentes natures, et avec des caracteres distinctifs, apparens ou faciles à reconnoître; par M. Daubenton, &c. Paris, chez Demonville, Pierres, Debure, Didot l'aîné, &c. in-8. de 36 pages.*

FIRST ORDER OF MINERALS.

SANDS, EARTHS, AND STONES *.

These Substances melt not in Water like Salts, burn not like Combustible Bodies, nor display the lustre of Metallic Matters.

CLASS FIRST.

Stones which give Fire with Steel.

Genus I. Quartz.

Crystalline Substance, Fracture vitreous, not lamellated.

Species I. Opaque, or semi-transparent Quartz.

- | | | |
|------------|---|---|
| Varieties. | { | <ul style="list-style-type: none"> 1. greasy. 2. grained. 3. lacteous. 4. foliated. 5. crystallized. |
|------------|---|---|

Species II.

* Here we give only part of M. Daubenton's table ; but in the history of salts and combustible bodies, his division of these matters shall be introduced. As we follow that table so faithfully as to copy even the

Species II. Transparent Quartz, ROCK CRYSTAL,

Two pyramids of six sides, with or without a six-sided prism between them.

Varieties.	{	1. crystallized.
		2. rough.
		3. white.
		4. red. <i>BOHEMIAN RUBY.</i>
		5. yellow. <i>OCCIDENTAL TOPAZ.</i>
		6. ruddy, or blackish. <i>SMOAKY TOPAZ.</i>
		7. green
		8. blue. <i>WATER SAPPHIRE.</i>
		9. violet. <i>AMETHYST.</i>
		10. iridescent.

Species III.

the characters in which the several parts of it are printed, we shall here subjoin the beginning of the Author's prefatory account of it.

“ Since the year 1779, this table has been exhibited in manuscript
 “ in the Hall of the Royal College, during the course of my lectures,
 “ and many copies of it have been taken. I have made repeated al-
 “ terations, according as I received from others, or acquired by my
 “ own observation, new information respecting mineralogy. I have
 “ even given up for a time my design of exhibiting on my table the
 “ results of a chemical analysis of the different minerals it contains as
 “ I had begun to do, because there have not yet been a sufficient num-
 “ ber analysed. My chief object in drawing out this table was to fa-
 “ cilitate the study of mineralogy. The best means for diffusing the
 “ knowledge of the sciences is to simplify their elements: Methodical
 “ arrangements contribute to this end. For though it be impossible
 “ to include all the properties of natural bodies, in any classification of
 “ them, yet such a classification is useful, convenient, nay even ne-
 “ cessary.

III. Quartz in agglutinated fragments, Grit-stone, or Siliceous Grit,

granulated fracture.

Varieties.	{	1. hard grit-stone
		2. friable
		3. Levant grit-stone. <i>Very fine grain</i>
		4. filtering stone. <i>Porous</i>
		5. glittering
		6. veined
		7. displaying figures of plants
		8. coarse grained.

IV. Quartz in separate grains, SAND,

vitreous surface.

Varieties.	{	1. angular
		2. round
		3. moving
		4. fluid.

Species

In the first volume of my Lectures on Natural History, the press, I shall give a particular explanation of my table, both the advantages and defects of my arrangement of will be pointed out. Here I shall only observe, that mine- in this table distributed into orders, classes, species, and va-

The distinctive characteristics of each article are printed in characters.

names in Roman capitals are those which I think most suit- the things which they are used to denote: Those in Italic are synonyma; the use of which is attended with inconve-, and which are inserted only that the knowledge of the mat- ick they denote may be the easier acquired.—F.

Species V. Quartz in concrete Masses.

Sandy and quartzose Breccias, or Pudding Stones.

Genus II. Semi-transparent stones,
vitreous fracture, sometimes conchoidal.

Species I. Agates,

of all colours, except milk white, fine red, orange, and green.

- | | | |
|------------|---|---|
| Varieties. | { | <ul style="list-style-type: none"> 1. clouded 2. punctuated 3. spotted 4. veined 5. onyx 6. irised 7. presenting the figures of herbs 8. exhibiting the appearance of moss. |
|------------|---|---|

Species II. Chalcedonies,

lacteous transparency.

- | | | |
|------------|---|--|
| Varieties. | { | <ul style="list-style-type: none"> 1. reddish 2. bluish 3. veined 4. onyx 5. iridescent. OPALS 6. round and solid. GIRASOLS 7. round and hollow. ENNE-
DRALS 8. in stalactites 9. in sediment 10. hydrophanes. |
|------------|---|--|

Species

III. Carnelians,

beautiful: red.

- Varieties. {
- 1. pale
 - 2. punctuated
 - 3. onyx
 - 4. exhibiting figures of herbs
 - 5. in stalactites.

IV. Sardonyx,

orange colour.

- Varieties. {
- 1. pale
 - 2. veined
 - 3. onyx
 - 4. presenting figures of herbs
 - 5. blackish.

V. Flints.

gray, white, reddish, blackish.

- Varieties. {
- 1. with tubercles
 - 2. in layers.

VI. The Prasem,

green.

- Varieties. {
- 1. green
 - 2. clouded
 - 3. spotted.

VII. Jade.

greasy polish.

- Varieties. {
- 1. whitish
 - 2. olive coloured

Species VIII. Petroflex,

transparency of wax, conchoidal fracture.

Varieties. { 1. white
2. reddish
3. veined.

Genus III. Opaque Stones,

vitreous fracture, sometimes conchoidal or dusky.

Species I. Miln Stone,

more or less porous.

Varieties. { 1. porous
2. dense, or full.

Species II. Pebbles,

concentric layers,

Varieties. { 1. spotted
2. veined
3. onyx
4. oculiform
5. exhibiting figures of herbs
6. concreted into breccias. **FL
DING STONES.**

Species III. Jasper,

vitreous fracture, often dusky, without concentric layers.

Varieties. { 1. green
2. red
3. yellow

4. brown

- Varieties. {
- 4. brown
 - 5. violet
 - 6. black
 - 7. grey
 - 8. white
 - 9. clouded
 - 10. spotted
 - 11. veined
 - 12. onyx
 - 13. flowered
 - 14. universal
 - 15. fragments united in breccias.

is IV. Scintillating Spar. **FELD-SPATH.**

Feld-Spath, regularly crystallized.

- Varieties. {
- 1. in oblique (angled) prisms, of four sides
 - 2. in six-sided prisms, with summits of two planes
 - 3. in ten-sided prisms, with summits of four facets.

Feld-Spath in confused crystals.

- Varieties. {
- 1. white
 - 2. pearl-grey. **FISH'S EYE**
 - 3. red
 - 4. red, with brilliant spangles.
NATURAL AVANTURINE
 - 5. green
 - 6. blue
 - 7. violet
 - 8. with green and blue stripes.
LABRADOIRE STONE
 - 9. with stripes of various colours,
CAT'S EYE.

Genus V. Crystal Gems,

*transparent and lamellated, not electrifiable by b
lone without friction.*

Species I. Red,

- | | | |
|------------|---|--|
| Varieties. | { | <p>1. Garnets
<i>crystallized with 12, 24
facets. There are
low, and brown, &c
nets</i></p> <p>2. The balass-ruby,
<i>rose-colour, octahedral &c</i></p> |
|------------|---|--|

Species II. Red and orange,

- | | | |
|------------|---|--|
| Varieties. | { | <p>3. Spinell ruby,
<i>fire-coloured, crystallized
like the balass-ruby</i></p> <p>4. Vermilion,
<i>crystallized like the garnet</i></p> <p>5. Hyacinthe-la-belle,
<i>crystallized under 4 be
sides with summits,
& rhomboidal facets.</i></p> |
|------------|---|--|

Species III. Orange-coloured,

- | | |
|----------|--|
| Variety. | <p>6. Hyacinths,
<i>crystallized like the hya-
cinthe-la-belle</i></p> |
|----------|--|

Species IV. Yellow,

- | | | |
|------------|---|--|
| Varieties. | { | <p>7. Oriental topaz,
<i>crystallized in 2 pyram
facets</i></p> <p>8. Saxon topaz,
<i>crystallized in prisms
sides, with summits
facets.</i></p> |
|------------|---|--|

Species V. Yellow and green.

- | | |
|----------|---|
| Variety. | 9. Peridots, CHRYsolITES.
<i>crystallized in prisms of 6 sides,
with pyramids of 6 faces.</i> |
|----------|---|

Species VI. Green.

- | | |
|----------|---|
| Variety. | 10. Peruvian emerald,
<i>crystallized in 6 sided prisms.</i> |
|----------|---|

Species VII. Green and blue.

- | | |
|----------|---|
| Variety. | 11. Aqua-marina,
<i>crystallized like the Saxon topaz.</i> |
|----------|---|

Species VIII. Blue.

- | | |
|----------|--|
| Variety. | 12. Oriental sapphire,
<i>crystallized like the oriental topaz.</i> |
|----------|--|

Species IX. Indigo.

- | | |
|----------|---|
| Variety. | 13. Indigo sapphire,
<i>crystallized like the oriental topaz and sapphire.</i> |
|----------|---|

Species X. Red and violet *.

- | | | |
|------------|---|--|
| Varieties. | { | 14. Syrian garnet,
<i>crystallized like the garnet</i>
15. Oriental ruby,
<i>crystallized like the oriental topaz and sapphire.</i> |
|------------|---|--|

O/3

Genus

* Gems formed without colouring matter are white. Note by Mr. Dabenton.

Genus VI. Tourmalins, Crystal Gems,

composed of laminae perpendicular to the axis of the crystal, and electrifiable by heat alone without friction.

- | | | |
|------------|---|---|
| Varieties. | { | 1. Brazilian ruby,
<i>red, in four-sided prisms, with
 pyramids of four facets</i>
2. Brazilian topaz.
<i>yellow, crystallized like
 Brazilian ruby.</i> |
|------------|---|---|

Genus VII. Tourmalins,

electrifiable by heat alone without friction, laminae perpendicular to the axis of the crystal.

- | | | |
|------------|---|--|
| Varieties. | { | 1. Tourmalins of Ceylon,
<i>transparent, orange-coloured,
 very little channelled on the
 face</i>
2. Spanish tourmalins,
<i>transparent in a strong
 orange coloured, very
 channelled</i>
3. Tourmalins of Tyrol,
<i>fissures traversing the prism</i>
4. Tourmalins of Madagascar
SHORTS OF MADAGASCAR
<i>opaque, black</i>
5. Lenticular tourmalins
6. Peridots of Ceylon,
<i>yellow and green, very
 channelled</i>
7. Peridots of Brasil,
<i>yellow and green, very
 channelled</i> |
|------------|---|--|

- Varieties. { 8. Brazilian emerald,
green
9. Brazilian sapphire,
blue*.
-

Genus VIII. Schorls,

*electrifiable by heat without friction, opaque crystals,
or long green semi-transparent needles.*

Species I. Crystallized Schorls,

- Varieties. { 1. in oblique prisms, with four
sides
2. in six-sided prisms
PIERRE DE CROIX
3. in six-sided prisms, with sum-
mits of 2 facets, or pyramids
of 3 or 4 facets
4. in prisms of 8 sides, with
summits of 2 facets.

Species II. In articulated fragments.

- Varieties. { 1. spathose schorl,
striated with sparry stripes
2. in masses. SCHORL PASTE
*brilliant points in the frac-
ture.*
-

Genus IX. Azure Stone,

opaque and blue.

- Varieties. { 1. purplish blue
2. blue.

O 4

CLASS

All these tourmalins, excepting the lenticular, are crystallized in
sided prisms, with summits of three or six facets. *Note by M.
caton.*

CLASS SECOND.

*Earths and Stones which neither give Fire with Steel,
nor effervesce with Acids.*

Genus I. Clays.

*when moist they are ductile ; when dry they are polish-
ed by a slight rubbing with the finger.*

Species I. Clays absolutely infusible.

Varieties { 1. used to make pots for the
 { glass-house
 { 2. for tobacco pipes.

Species II. Clays partly fusible.

Varieties. { 1. for porcelain
 { 2. for English potter
 { 3. for stone-ware.

Species III. Clays entirely fusible.

Varieties. { 1. for common pottery.
 { 2. for delft-ware
 { 3. for Dutch tiles
 { 4. for tiles
 { 5. for bricks.

Genus II. Schistus,

argillaceous and foliated fracture.

- | | | |
|------------|---|----------------------------------|
| Varieties. | { | 1. black stone |
| | | 2. common schistus |
| | | 3. writing slate |
| | | 4. polishing stones |
| | | 5. green stone |
| | | 6. hone |
| | | 7. fragments united in breccias. |

Genus III. Talc,

polished glistening laminae, without spatulose fracture.

Species I. Talc in large leaves.

Variety. Muscovy talc.

Species II. In small leaves.

Variety. Mica.

Genus IV. Steatites,

feel greasy, like tallow.

Species I. Steatites in layers.

- | | | |
|------------|---|---------------------------------------|
| Varieties. | { | 1. fine French chalk (de Briançon) |
| | | 2. coarse French chalk (de Briançon.) |

Species II. Compact Steatites.

- | | | |
|------------|---|-------------------------------|
| Varieties. | { | 1. soap rock (Pierre de lard) |
| | | 2. Spanish chalk. |

Species III. Lapis Ollaris.

- | | | |
|------------|---|----------------------------|
| Varieties. | { | 1. Como stone |
| | | 2. foliated lapis ollaris. |

Genus

Genus V. Serpentine,

the polish and colours of marble.

Species I. Opaque Serpentine.

Varieties. { 1. spotted
2. veined.

Species II. Semi-transparent Serpentine.

Varieties. { 1. granulated
2. fibrous.

Genus VI. Amianthus,

filaments not calcinable, leaves or flakes lighter than water.

Species I. Amianthus with soft fibres.

Varieties. { 1. with long fibres
2. with short fibres.

Species II. Amianthus with hard (brittle) fibres.

Varieties. { 1. Asbestos, easily divisible into parts (muscovite)
2. Asbestos, not easily divisible into parts (hornblende)

Species III Amianthus in flakes or leaves

Varieties. { 1. fossil leather
2. fossil cork.

Genus VII. Zeolite,

crystallized in divergent radii, or transmutable into a gel by solution in acids.

Species I. Crystallized Zeolite.

Species

es II. Compact Zeolite.

- Varieties. { 1. white
2. blue
3. red.
-

Genus VIII. Fluor Spar,

gments with triangular faces, all inclined to each other.

ies I. Fluor Spar in crystals.

- Varieties. { 1. octahædrons
2. cuneiform octahædrons
3. with 14 faces
4. cubical.

ies II. Fluor Spar in irregular Masses.

Genus IX. Ponderous Spar,

rhomboidal fragments, the lateral faces perpendicular to the bases.

ies I. Crystallized Ponderous Spar.

- Varieties. { 1. in rhomboidal plates
2. in octahædrons with acute summits
3. in octahædrons with obtuse summits
4. in hexagonal plates with acute summits
5. in hexagonal plates with obtuse summits
6. in tables

(lenticular)

Species II. Ponderous Spar crystallized confusedly

BOLOGNA STONE.

Genus X. Ponderous Stone. **TUNGSTEN,**

*resembling Fluor Spar in the form of its fragments,
but much heavier ; it becomes yellow in acids.*

CLASS THIRD.

Earths and Stones which effervesce with Acids.*

Genus I. Calcareous Earths.

Effervescence with Acids.

Species I. Compact.

Variety. Chalk.

Species

* Though modern chemists consider these substances as neutral salts, formed by the union of chalk with the carbonic acid, we subjoin them here after the earthy matters, in order to give a connected view of M. Daubenton's method. Naturalists, who employ in their arrangements none but exterior and striking characteristics, must consider these substances as genuine earths: but in the history of saline matters, they will be viewed in a different light. F.

ies II. Spongy.

Variety. Stone-marrow,

ies III. In powder.

Variety. Fossil Flour.

ies V. Consistency of cream.

Variety. Lac lunæ.

ies V. Figured.

Variety. Congealed.

Genus II. Calcareous stones,

indifferent colour and polish.

ies I. Coarse grained.

SPECIMEN.

Limestone from Arcueil.

ies II. Fine grained.

SPECIMEN.

The Thunderstone.

Genus III. Marbles.

Granulated fracture, fine colour and polish.

ies I. Marbles of six colours.

Varieties

Varieties. { White, grey, green, yellow, red,
and black.
SPECIMEN.
Marble from Wirtemberg.

Species II. Marbles of two colours.

Varieties. { 15 in number, formed by the com-
bination of 6 colours, 2 together.
SPECIMEN.
white and grey.
Marble of Carrara.

Species III. Marbles of three colours.

Varieties. { 20 in number, formed by the com-
bination of 6 colours, 3 together.
SPECIMEN.
grey, yellow, and black.
Lumachello.

Species IV. Marbles of four colours.

Varieties. { 15 in number, formed by the com-
bination of 6 colours, 4 together.
SPECIMEN.
white, grey, yellow, and red.
Brocatello from Spain.

Species V. Marbles of five colours.

Varieties. { 6 in number, formed by the combi-
nations of 6 colours, 5 together.
SPECIMEN.
white, grey, yellow, red, and black.
Breccias of Old Castle.

Genus IV. Calcareous Spar.

Regular form, spathose fracture.

Species I. Crystallized calcareous spar.

- | | | |
|------------|--|---|
| Varieties. | { | 1. obtuse rhomboidal figure. |
| | | <i>Iceland Spar.</i> |
| | | 2. lenticular rhomboidal figure |
| | | 3. lenticular rhomboidal figure |
| | | 6 triangular faces |
| | | 4. acute rhomboidal figure |
| | | 5. with 12 pentagonal faces |
| | | 6. with 3 triangular faces |
| | | 7. six-sided prism |
| | | 8. six rhomboidal sides, with 6 faces
lozenge-wise |
| | | 9. with 12 scalene triangular faces |
| { | 10. with 12 faces of 4 or 5 sides, and
6 quadrilateral facets | |
| | 11. with 6 hexagonal faces, and 12
facets of four sides. | |

Species II. Striated calcareous spar.

- | | | |
|------------|---|--------------------------|
| Varieties. | { | 1. with parallel striæ |
| | | 2. with divergent striæ. |

Genus V. Concretions.

Successive coats.

Species I. Stalactite Concretions.

- | | | |
|------------|---|--------------------------|
| Varieties. | { | 1. in columns |
| | | 2. tabular |
| | | 3. resembling alabaster. |

Species

Species II. Concretions by incrustation.

Specie III. Concretions by sediment.

Varieties. { 1. by horizontal sediments
2. by rounded sediments.

CLASS FOURTH.

Mixed Earth and Stones.

Mixed earths.

Genus I. Sand and Clay.

Species. Sand for founders.

Variety. Sand from Fontenai-aux-roses.

Genus II. Sand and calcareous earth.

Genus III. Clay and calcareous earth.

Species. Marle.

Varieties. { 1. marle, Armenian bole
2. marle, terra sigillata
3. stone for taking spots out of cloth
(pierre a detacher)
4. fuller's earth
5. porcelain earth
6 pipe clay
7. potter's clay (terre a faience)
8. white marle
9. foliated marle
10. marle for manure

Mixed

Mixed Stones,

OF TWO GENERA,

- and scintillating spar - - Granitic.
- and schorl - - - - Granitic.
- and steatites - - - - Quartzose steatites.
- and mica - - - - Micaceous quartz.
- rent quartz and mica - Micaceous crystal.
- n grit and gem-stone - { 1. Garnet on grit-stone;
2. Garnet in grit-stone.
- n grit and mica - - - Micaceous grit.
- n grit and calcareous mat- { 1. crystallized grit.
2. grit in stalactites.
- in sand and opaque stone { sandy and siliceous breccias.
- n sand and schistus - - { scintillating schistus.
HORNSTONE. TRAP.
- n sand and zeolite. - - scintillating zeolite.
- ting spar and schorl paste ophites.
- nsparent stone, with opaque stone { jasperated agate, or agatized jasper.

P

Schorl

Schorl and mica - - - -	{ micaceous spathose schorl.
Schistus and mica - - - -	micaceous schistus.
Schistus and marble - - - -	Florence stone.
Serpentine and marble - -	{ 1. green Egyptian marble. 2. sea green marble. 3. green antique marble. 4. green marble of Suza. 5. green marble of Varalta.
Ponderous spar and calcareous matter	{ alkaline ponderous spar.

OF THREE GENERA.

Quartz in sand, schistus and mica	rough wheat-stone.
Quartz, gem, and mica - -	garnet rock.
Quartzose paste, scintillating spar in small fragments, and schorl	{ porphyry.
Quartzose paste, scintillating spar in large fragments and schorl	{ serpentine. <i>hard serpentine.</i>
Quartz, schorl, and steatites - -	tuberculous rock.
Quartz, scintillating spar, and schorl	{ granite

OF FOUR GENERA.

Quartz, scintillating spar, schorl, and mica	{ granite.
--	------------

CONSISTING OF MORE OR FEWER }
 GENERA, UNITED IN BRECCIAS } universal breccias.

DOUBLE BRECCIAS.

Varieties. { 1. Fragments of porphyry, and paste
 of porphyry.
 2. Fragments of granite, and schorl
 paste.

VOLCANIC PRODUCTS*.

CLASS I. Lavas, or Matters formed by Volcanoes;
 volcanic Matters.

Species 1. Porous Scorizæ.

Varieties. { 1. in irregular masses.
 2. in striped masses.
 3. in the form of stalactites:
 4. in fragments. LAPILLO.
 5. in small fragments.
 POUZOLANA.
 6. in dust.
 VOLCANIC CINDERS.

P 2

Species

L. Daubenton places volcanic products at the end of minerals,
 not ranking them under any of the four orders of which his me-
 thod consists. As their history is usually studied along with that of
 I have a

Species II. Basaltes,

compact and scintillating, blackish cinereous fracture, &c. with brilliant points, without small plates, like those of the scintillating schistus.

- | | | |
|------------|---|---|
| Varieties. | { | 1. in irregular masses.
2. in balls.
3. in tables.
4. in prisms of 3, 4, 5, 6, 7, 8, or 9
fides.
5. in articulated prisms. |
|------------|---|---|

Species III. Glafs.

- | | | |
|------------|---|---|
| Varieties. | { | 1. in separate fibres.
GLASS GALL.
2. in agglutinated fibres.
PUMICE STONE.
3. in compact masses.
VOLCANIC SCORIA.
LAPIS OBSIDIANUS. |
|------------|---|---|

Genus II. Volcanized Matters; that is to say, matters, altered by the heat of volcanoes, *appearing to have been baked, calcined, melted, or vitrified.*

Species I. Granite.

II. Garnet

III. Hyacinth.

IV. Mica.

V. Peridot.

VI. Quartz.

VII. Schorl.

VIII. Scintillating spar.

IX. Calcareous Substances.

X. Baked Earths, Tripoli

STONES, with the nature of which we are not yet sufficiently acquainted to reduce them under certain Classes.

Jargon of Ceylon.

crystals in rectangular prisms, with pyramids of 4 triangular faces.

The name of Jargon appears to be given to many stones, the particular structure of which is hitherto unknown.

Macles,

in square or cylindrical prisms, the transverse section of which exhibits a blue cross.

The macle has been considered as a schorl; but the opinion has not been proved.

White Crystals,

in flattened prisms with 10 sides, with two summits of four faces, one of which forms a concave, the other a convex angle.

Violet or green Crystals.

rhomboidal, with two facets instead of two opposite angles.

These white, violet, and green crystals, have obtained the name of Schorls, although they do not appear to be of the same nature with sc^l

C H A P. III.

Of the Classification of Earths and Stones according to their Chemical Properties.

THOSE chemists who have engaged in the the study of minerals, have endeavoured to establish distinctions among them, founded on their chemical properties. And though a sufficient number of earths and stones has not yet been examined, to enable us to form very accurate or complete arrangements of them on these principles; yet it is certainly an object of importance to the student of mineralogy to know the present state of chemical science respecting these substances, and what advantage the mineralogist can derive from it in arranging them.

Of all the philosophers who, since Cronstedt, have attempted to arrange earths and stones by their chemical properties, Bucquet, Bergman, and Kirwan, have been the most successful, and have given the most complete systems. As each of these gentlemen has followed a peculiar mode of arrangement, and as each of their methods possesses some undeniable advantages, we shall here lay before our readers successive views of the three systems, and shall at the same time point out their several defects.

*§ I. Of the Chemical Division of Earths and Stones
proposed by BUCQUET.*

BUCQUET, after many laborious researches with a view to this object, at length formed, a little before his death, a system of earths and stones, on the compound principle of their chemical properties and their exterior characteristics, as observed by naturalists, which he had resolved to follow in his future courses of lectures. In repeated conversations with him during the lingering illness which ended in his death, I obtained a full account of that method; which was communicated to the public in the first edition of this work. I shall now again give it as it then appeared, only adding a few notes, to take notice of the improvements which this branch of the science has received since the year 1779.

According to Bucquet, earths and stones should be arranged under three divisions: the first comprehending simple earths and stones; the second, compound earths and stones; and the third, mixtures of earths and stone.

Simple earths and stones, in a state of purity, are insipid, dry, hard, insoluble, and infusible. Whenever any of them appear to possess these properties in a less perfect degree, more especially when any of them appear susceptible of fusion, they are to be considered as not pure, but alloyed by the mixture of some extraneous matter. Such as are pure, admit not of decomposition by chemical analysis; but the number of pure stones is much more scanty than Bucquet thought it.

Compounds earths and stones are to be regarded as combinations of the simple earths with saline or metallic substances. These combinations have been effected by the operation of fire or water in the great laboratory of nature. Their chemical characteristics are, to melt easily, to suffer vitrification from the action of fire, and to be separable into several simple substances by the action of solvents, more especially by the action of acids.

Mixed earths and stones are easily distinguished by inspection. They seem to be formed by the irregular aggregation of several earths and stones, both simple and compound. To analyse them, the several different matters of the irregular aggregate must be divided and examined each by itself. Their peculiar natures may be then certainly determined by chemical experiments.

D I V I S I O N I.

Simple Earths and Stones.

THESE are divided into four orders.

ORDER I. VITREOUS STONES.

THESE are extremely hard, and perfectly transparent; of a vitreous fracture; give fire with steel; and suffer no alteration in transparency or hardness from the action of heat.

This first order contains two genera; rock-crystal and vitreous precious stones.

Genus

Genus I. *Rock-Crystal.*

ROCK-CRYSTAL exhibits all the properties of vitreous bodies in the most eminent degree. Its fracture, which is similar to that of glass, distinguishes it from the following genus.

It may be subdivided into species.

1. By the Property of Form.

Species.

1. Insulated hexahædral crystals, which two hexahædral pyramids. The Abbé Rochon has observed, that these produce a double refraction.
2. Hexahædral crystals, united in groups, with one or two points.
3. Tetrahædral, duodecahædral, flattened, &c. crystals. Those of which the facets are varied and irregular are always hexahædral.
4. Rock-crystal in masses, from Madagascar. It produces only a single refraction.

2. By the Property of Colour.

5. Reddish rock-crystal.
6. Smoky crystals.
7. Black crystals.
8. Yellow crystals.
9. Blue crystals.
10. Green crystals.

3. By accidental Circumstances.

Species.

11. Hollow rock-crystal.

12. Containing water.
13. One crystal inclosed within another (*emboités*).
14. Rounded ; pebbles from the Rhine.
15. Incrusted with metallic calces.
16. In *gæodes*.
17. Containing amianthus.
18. Containing schorl.
19. Incrusted with pyrites.

Their formation by water is proved,

1. By their transparency.
2. By the form of small crystals.
3. By the inclosure of one crystal in another.
4. By their inclosing substances alterable by fire.

They are cut and polished into vases and toys.

Genus II. *Vitreous Precious Stones.*

THE precious stones which we rank under this genus, have all the properties which characterise rock-crystal, and more especially its inalterability by fire. Though this may seem extraordinary, since Bergman informs us, that he found these stones to be compositions of several different matters ; yet in their hardness, their transparency, and the manner in which they are affected by fire, they differ but little from rock-crystal ; they are, however, inferior in hardness, their colour is not so clear and lively, and their fracture is lamellated. The differences among precious stones, particularly with regard to the manner in which they are affected by fire, induced Bucquet to se-

parate

parate them, and to arrange them among those of the orders of stones to which they have the nearest resemblance.

The four precious stones which we distinguish by the denomination of vitreous, are,

Species.

1. The oriental topaz.
2. The hyacinth.
3. The oriental sapphire.
4. The amethyst.

M. Daubenton has always considered this last as a quartz crystal.

ORDER II. QUARTZOSE STONES.

THESE are not so hard or transparent as the former; their fracture is vitreous; and they give fire with steel. Heat deprives them of hardness and transparency, and reduces them to a white opaque earth *. Under this order we arrange four genera.

Genus I. *Quartz.*

It possesses all the above characteristics.

Species.

* It was on account of its being liable to alteration by fire, that Bucquet distinguished quartz from rock-crystal, and arranged it under a particular genus. He likewise observed, that quartz dipped in water, after having been for several times successively heated red hot, communicated to that fluid a degree of acidity. Future experiments will determine the certainty of this fact—F.

Species.

1. Transparent quartz, crystallised in hexagonal pyramids ; its prisms either not observable, or at least very short.
2. Transparent quartz in masses.
3. Opaque or laccous quartz.
4. Greasy quartz.
5. Carious quartz.
6. Green, blue, or violet quartz ; prism of amethyst.
7. Yellow quartz, of a lamellated fracture.

Topaz { Saxon.
 { Brazilian.

These topazes possess all the characteristics of quartz.

Genus II. *Flint, Agate.*

FLINTS and agates are small round masses, generally opaque, sometimes semi-transparent, either hollow or solid, of various colours, and disposed in strata,—in chalk, as is the case with flints ; or in clay, as agates. Their fracture is sometimes scaly.

Species.

1. Grey flint.
2. Yellow flint.
3. Red flint.
4. Corneous flint ; gun-flint.
5. Brown Egyptian flint.
6. Transparent clouded flint ; German agate.
7. Red agate ; male cornelian.
8. Pale red agate ; female cornelian.
9. Brown or yellow agate ; sardonyx.

10. Agate

ies.

10. Agate-onyx, in concentric laminæ.
11. Agate-Cameo, in horizontal layers; but the appearance of the laminæ, and their disposition with regard to the figure of the stone, depends in a great measure on the manner in which it is cut.
12. Figured agates. { Dendrites; herborized agates*.
Anthropomorphites.
Zoomorphites.
Uranomorphites.
13. Agate, apparently mouldy; marked with small green points, generally owing to mosses.
14. Agate of four colours; elementary.
15. Grey agate; grey chalcedony.
16. White, lacteous, or chalcedony agate. { in layers.
in stalactites.
round, cacholong.
17. White agate, with a wavy reflection of the light. { Lapidaries agate, *chatoyant* lustre.
Cat's eye.
Oculus mundi, or hydrophanes.
Opal.
Girasol.
18. Brown agate, with brilliant gold-coloured points. Aventurine.
19. Oriental agate.
20. Agate containing water (Enhydre).

The formation of quartz, agates, and flints, is owing to water, as is proved,

1. By

* M. Daubenton has shown, in a memoir read to the Academy, that herborised stones contain very fine mosses, or small grains of black ore.—F.

1. By their form.
2. By their layers.
3. By their mosses.
4. By their containing water.
5. By the organized matters mixed with them, as in the mossy or mouldy agates.

This also appears from the circumstances and properties of the gæodes. These are stone boxes, filled with crystals: they contain flint and quartz arranged in concentric layers.

Genus III. *Organic Matters converted into Silix, or Agate.*

THESE are distinguished from the other genera of this order, by possessing the characteristic properties of quartzose stones under an organic form*.

Species.

1. Wood petrified, but still fibrous, and susceptible of polish.
2. Wood, the texture of which indicates its particular kind. Fir.
3. Sea-urchins and madrepores converted into flint.
4. Shells converted into agate.
5. Carpolites: these have been mistaken for petrified

* It would perhaps be a much more natural mode of division, to arrange under a distinct class, all such animal and vegetable substances as have suffered alteration from lying under ground. The name of that class might be fossils, and it might be placed at the end of the organic kingdoms.—F.

Species.

trified fruits; they are properly small *ludi-belmontii* filicified.

6. Entrochites.

7. Lapis frumentarius filiceus.

This last stone gives fire with steel, but does not effervesce with acids. It seems to be formed by an assemblage of cornua ammonis divided perpendicularly to their volutes.

There are two opinions concerning petrification. Some think that organized bodies are entirely transmuted into stone: others are of opinion, that the void spaces formed by animal substances in soft earths, and the interstices in the fibrous texture of vegetables, are gradually filled up by an accumulation of earthy matter. But we can pretend to no certain knowledge of the cause of this phenomenon. Vegetable matters are observed to become almost always quartzose, and scarce ever calcareous; while animal substances, on the contrary, become generally calcareous, and seldom quartzose*. From this fact we may almost conclude, that no real petrification takes place, and that organized bodies are not converted into stone: For, 1. Shell-fish and madrepores only lose their mucilage or animal gluten, by putrefaction, and are reduced to calcareous skeletons, which existed during the life of the animals: 2. What is said to be petrified wood, is nothing else than

* Since the discovery of the fluoric acid gas, which possesses the property of decomposing quartzose earth, some naturalists have conjectured, that petrification may be produced in a similar manner. But this is to be regarded as mere conjecture, till such time as it be shown that there exists in the interior parts of the earth an acid which maintains quartzose earth in a state of solution.—F.

than an accumulation of vitrifiable earth in moulds formed by putrefied vegetables. As the fibres of the vegetable body are gradually destroyed by putrefaction, a quantity of quartzose earth is deposited by the water in the space which they occupied : a quartzose stone is thus formed of the very figure and texture of the vegetable body, but not a particle of this substance enters into its composition.

Genus IV. *Jasper.*

JASPER possesses all the characteristics of quartzose stones. It is infusible, but loses its aggregation by fire : it is extremely hard, opaque, and variegated with divers colours ; its fracture is dusky and vitreous. It is not often found arranged in beds ; it generally composes considerable masses or veins in rocks : It is also found in small round lumps. Most specimens of jasper that we have seen, are mixtures of quartz and chalcodony. It sometimes contains calcareous spar.

Naturalists have divided jasper into a great many species. These may be reduced to the following.

Species.

1. White jasper.
2. Grey.
3. Yellow.
4. Red.
5. Brown.
6. Green.
7. Veined.
8. Spotted.
9. Green, with red points : bloody jasper.
10. Flowered.

Jasper is used for making toys, particularly cups and
ls. There are many antique engravings on stones of
s kind.

Genus V. Grit, or Free-stone.

GRIT-STONE is opaque, of a granulated fracture,
not softer than quartz or flint ; it is found in large
flakes, of various degrees of hardness, and sometimes
or sometimes coarser grained.

ies.

1. Grit Crystallised in rhombi. M. de Laffone has
shown that these owe their form to the chalk
incorporated with them *.
2. Grit in the form of cauliflowers.
3. In stalagmites.
4. White.
5. Grey.
6. Red.
7. Black, or Brown.
8. Veined.
9. Figured, or herborised.
10. Grit, of which the aggregation is destroyed ;
sand.

Sand appears under the following varieties :

ieties.

1. Quick-sand.
 2. Angular sand.
 3. Sand rounded by the action of water.
 4. Pure
- VOL. I. Q

* *Memoirs of the Academy of Sciences for the year 1777—F.*

Varieties.

4. Pure white sand.
5. Micaceous sand ; glarea.
6. Yellowish, argillaceous ; founder's sand.
7. Ferruginous sand ; yellow.
8. ————— black.
9. Blue sand ; from copper.
10. Violet sand ; from tin.
11. Auriferous sand.

ORDER III. ARGILLACEOUS EARTHS *and* STONES.

THESE are greasy ; clammy, or pliant ; stick to the tongue ; foliated ; frequently coloured ; and disposed in large masses, and in layers.

Their force of aggregation is less than that of quartzose stones ; but they have a greater tendency to combination, and are therefore often altered. Heat contracts and hardens them, so as to give them the appearance of quartzose stones, and to cause them to give fire with steel as well as those. Water reduces them to a paste, divides, and purifies them ; they absorb water, and retain it with such force of combination, that they cannot be again totally deprived of it.

Part of the substance of these stones combines with acids. Some chemists have taken clay to be nothing but siliceous earth altered by the sulphuric acid ; but that opinion has not yet been fully proved.

Many naturalists have entertained an opinion, that vitrifiable earths, after being long exposed to the agency of water, air, and heat, are separated and reduced into fine soft particles, capable of combination with water, and thus pass into the state of clay. This theory
being

; founded on some accurate observations, merits respect than the former : But the evidence of nei- amounts to demonstration.

ese two properties of mixing with water so as to ose a ductile paste, and again becoming hard by sion of fire, render clay fit for being wrought tiles, bricks, pottery, delft-ware, and porcelain : n account of these makes a part of the history of ind of earths.

turalists have described a great many kinds of stones onging to this order ; but they have confounded a- them many false clays and compound stones ; are, of the last, serpentine, zeolite, trapp, &c.

e name of *clay* properly belongs to none but such ; as are hardened by fire, are diluted in water, ombine with the sulphuric acid to form alum.

cquer having examined a great many of them, none absolutely pure *. Many of them owe colour and fusibility to their being mixtures of is combustible and metallic substances.

cquet divided them into four genera.

Genus I. *Soft Ductile Clays.*

ese, when dug from the bed or quarry, may be ed ; but they become dry in the open air.

- . White clay ; pipe clay.
- . Sandy clay.
- . Clammy blackish clay ; for white pottery.
- . Clay, with a mixture of mica, kaolin ; partly fusible ; for porcelain,

Q 2

G. Me.

Species.

5. Metallic clay, fusible ; terra figillata ; Armenian bole
6. Pyritous clay ; fusible ; blue, green, marble ; used in common pottery.

Genus II. *Dry, Friable Clays ; Clay of Tripoli.*

ALL those clays which Bucquet ranked among the tripolis, are dry in the interior parts of the earth. They are all found in beds or layers, often very thin, and arranged one above another. All of them crumble down into dust under the finger, and absorb water readily ; they likewise stick to the tongue.

Species.

1. Dry, grey, foliated clay ; fullers earth.
2. Red tripoli. Some people take this to be a volcanic product.
3. Grey tripoli.
4. Black tripoli.
5. Rotten stones of an olive grey colour.

Genus III. *Schistus.*

SCHISTI are foliated stones which split readily into plates : they are a mixed fusible substance ; they are placed in huge masses in the bowels of the earth, and always in an oblique direction. Almost all quarries of schisti exhibit on their exterior surface, and in the uppermost layers, impressions of plants of the rush and fern kinds, &c. of shells, fishes, or insects, &c.

Species

Species.

1. Black schistus, tender ; ampelite.
2. Fissile schistus ; slate.
3. Black, hard schistus ; writing slate.
4. Red, brown schistus, &c.
5. Schistus marked with impressions of vegetable or animal bodies.
6. Very hard schistus, naxian stone, used for whetting razors.

Genus IV. Feldt-Spar.

It exists in the form of rhomboidal plates ; its fracture is spathose, and it gives fire with steel : It is for this reason called *scintillating spar*. Though harder than schistus, it is fusible. Bucquet supposed it to be an argillaceous stone, coloured by a mixture of iron. M. Monnet considers it as a compound of quartz, clay, magnesia, and a small portion of calcareous earth. Its being but little known is the cause of this diversity of opinions concerning its nature. A more accurate examination must determine its true character *.

Q₃

Species

*. Father Pini, an Italian naturalist, was the first who described crystallised feldt-spar. Since his discovery, it has been found in many places in France. Very regular feldt spar crystals are found at Roanne in Forez. I have given a minute description of that which is found in the Alençon granites, and which is one of the most regular and beautiful with which I am acquainted, in my *Memoires de Chemie*.—F.

Species.

1. Prismatic feldt-spar *.
2. White feldt-spar †.
3. Red feldt-spar.
4. Green feldt-spar,
5. Blue feldt-spar.

ORDER IV. FALSE CLAYS.

THESE resemble clays only by having a foliated texture, and greasy appearance ; some of them indeed harden by fire.

They differ from clay, as not being fit for composing a paste with water, and as being most of them fusible in fire. They combine with the sulphuric acid to compose a salt in the form of needles, which suffers no alteration from air, but is soluble in four or five parts of water, and does not swell in fire ; in a word, is not alum. Bucquet, who had examined a great many of these stones, gave these as their characteristics : but as they are very little known, they may still be ranked near the clays ‡.

Genus

* M. Daubenton ranks this among the scintillating stones. It is distinguished by three characteristics from every other species of stones ; its texture is spathose ; it yields a changing or *chatoyant* lustre ; and it gives fire with steel. With these characteristics, this genus must contain more species than Bucquet ascribed to it. M. Daubenton included under it the fish's eye, the avanturine, and the labradore stone.—F.

† It has been ascertained by experiment, that 100 parts of white feldt-spar, contain about 67 silice, 14 alumine, 11 barytes, and 8 magnesia.—H.

‡ The Abbé Mongez, in his Introduction to Bergman's *Sciagraphy*, observes, that these stones might be with more propriety named *magnesian stones*. I should willingly agree to use that name ; but I believe a number of experiments are necessary before we can receive it as expressive of their nature.—F.

Genus I. *Lapides Ollares, hard.*

Their texture can scarce be called foliated ; their appearance is greasy ; and they are susceptible but of an different polish.

cies.

1. Grey, Swedish lapis ollaris.
2. Greenish lapis ollaris ; Swedish colubrine.
3. Yellowish lapis ollaris ; Chinese soap-stone.
4. Bright green lapis ollaris ; jade. Bucquet thought the nephritic and Otaheitean stones to be varieties of the jade. The jade is very hard, and gives fire with steel. Bucquet appears to have followed Pott in placing it among the lapides ollares.
5. Dirty green lapis ollaris ; colubrine.
6. Serpentine. A stone of a deep green, or rather blackish colour, with black spots or veins, like a serpent's skin. On account of its appearance, we have placed it at the end of the lapides ollares ; it seems to be a compound.

Genus II. *Soft Lapides Ollares ; Steatites, or Smectites.*

THESE are more of the nature of soap than the foregoing genus. They may be easily cut ; they froth in water ; and some of them have externally a striking resemblance to soap.

Species.

1. White, compact steatites ; Briançon chalk.
2. Bright Briançon chalk ; the druggists Venetian talc.
3. White, Norwegian steatites.
4. Red marbled Norwegian steatites.
5. Reddish Norwegian steatites.
6. Green compact steatites from Norway.
7. Green and red steatites from Norway.
8. Green, foliated ; soft colubrine of Norway.
9. Black steatites ; used by stone-cutters.
10. Sparkling grey steatites ; plumbago, molybdena, and very improperly black lead. Plumbago being reduced to powder, and wrought into a paste with a mixture of isinglass, is inclosed in small cylinders, which are cut to a point at one end, and used as pencils or crayons*.

Genus

* Since the death of Bucquet and the first edition of this work Messrs. Scheele, Gahn, and Hielm, have very successfully investigated the nature of plumbago ; they have found it to be a carbure of iron. We shall give its history after that of sulphur. The same chemists, more especially M. Scheele, have made a very proper distinction between plumbago and molybdena, which former naturalists had always confounded together. M. Scheele considers molybdena as a compound of sulphur with a certain acid, to which he gives the name of the *molybdenic*. (*See the history of metals.*) It is plumbago which is used for pencils.—F.

In England, the plumbago used for pencils is not ground to powder and mixed with isinglass ; but cut into long slender pieces and inclosed in wood. Those described by the author are an inferior kind.—H.

Genus III. *Talc.*

It consists of polished glittering plates, disposed one over another, and of a gelatinous transparency. These laminæ or plates are sometimes crystallised in an hexagonal form, or in sections of six-sided prisms. A strong fire melts it into a coloured glass.

Species.

1. Talc in large transparent plates; Muscovy glass.
2. Talc in very small silvered spangles.
3. Talc in very small golden spangles. These two kinds are used to dry writing, under the name of *gold* or *silver powder*.
4. Talc worn into the form of pebbles.
5. Talc in black spangles.
6. Talc in mixed brilliant spangles.

Genus IV. *Amiantbus, Asbestos.*

THE stones of this genus consist of fibres or threads disposed parallel to one another, or interwoven like the texture of a web. These threads are sometimes stiff, sometimes flexible; and they differ from one another in colour, length, and thickness. The ancients spun them, and made of them a kind of cloth, to which they gave the name of *incombustible linen*, in which they burnt the bodies of the dead, in order to preserve their ashes, &c.

Amianthus melts, in a strong fire, into an opaque coloured glass.

Species

Species.

1. Hard grey asbestos, with parallel threads; ligneous asbestos.
2. Hard green asbestos, with parallel threads.
3. Hard green asbestos; its threads in bundles.
4. Asbestos, with diverging fibres.
5. Hard asbestos, with soft fibres.
6. Hard amianthus, with parallel greenish fibres.
7. Hard amianthus, with parallel white fibres.
8. Amianthus in bright white bundles.
9. Amianthus in hard yellowish bundles.
10. White flexible amianthus.
11. Grey amianthus.
12. Mountain flesh.
13. Mountain leather.
14. Mountain cork.

D I V I S I O N I I.*Compound Earths and Stones.*

THESE cannot be distinguished by ocular observation from those of the former division. As to the nature of their composition, they are formed of an homogeneous matter, almost always coloured, generally opaque, but sometimes transparent; most of them are regularly crystallized. They are distinguished into genera by form and colour. They are all very fusible, and afford glass of various kinds. Their fracture is sometimes vitreous, sometimes scaly. In these substances nature has combined together earths, salts, and metals.

Bucquet

Bucquet divided these stones into two orders: Under the first he comprehended earths and stones compounded with water, which he characterised as products of that element. This order again he divided into two genera, namely, ochres and zeolite. Under the second order he reckoned schorl, macles, trap, azure stone, fusible precious stones, volcanic crystals, volcanic glass, and pumice stones: these eight kinds of stone he considered as formed by the action of fire. We have undertaken to give an account of the ideas of that celebrated chemist concerning the nature and classification of stones; but as the distinction between these two orders is not established by a sufficient number of conclusive facts, and as M. Bucquet himself offered them only as hints, we shall here give the history of these genera successively, without dividing them into orders.

Genus I. *Ochres.*

OCHRES are less easily diluted in water than clays; they are friable and soil the fingers; they are coloured by metallic matters, generally by iron. When exposed to a strong fire, they assume a deeper colour: violent heat melts them. They are used in painting.

Species.

1. Yellow ochre.
2. Red ochre, blood coloured.
3. Green ochre; Verona earth.
4. Brown ochre; Umber earth.

Genus II. *Zeolite.*

THE zeolite, first described by Cronstedt, is a stone composed of needles diverging from a common centre. It neither gives fire with steel nor effervesces with acids: When exposed to fire it swells and produces a white opaque glass resembling enamel. By distilling it in a retort, a considerable quantity of water is obtained. The residue, according to Bergman, consists of siliceous, aluminous, and calcareous earth. Bucquet, who analysed it, mentioned his having found in it a very little siliceous earth, and a particular kind of earth neither aluminous nor calcareous; which with the sulphuric acid afforded a salt crystallized in small shining plates, resembling the boracic acid, and to which he thought proper to give the name of *zeolitious earth*. These two earths are crystallised together by the help of water, which forms more than an eighth part of the composition: for, from an ounce of white zeolite, from the island of Ferro, M. Bucquet obtained a dram and an half of water*. The property of composing a jelly with various acids is not peculiar to it; azure stone, tin, and several iron ores, &c. are capable of a similar composition†. Its origin and formation are unknown; abundance of it is found among the products of volcanoes.

* See *les Mémoires de Savans étrangers*, Tome IX. p. 576.

† M. Pelletier, apothecary, a disciple of M. d'Arcet, has given in the *Journal de Physique* (1782, vol. XX. page 420.) a memoir on the analysis of the zeolite of Ferro. He has found, by the most accurate experiments, that 100 grains of this stone contain 20 grains of aluminous, 8 grains of calcareous, and 50 of siliceous earth, and 22 grains of water. Consult that memoir.—F.

noes. There is great plenty of in the isle of Ferro. We are acquainted only with five kinds of it.

Species.

1. White zeolite, in transparent fasces.
2. White zeolite, in compact fasces.
3. Red zeolite.
4. Green zeolite.
5. Blue zeolite.

Neither the red, the green, nor the blue, has yet been examined.

Genus III. *Schorls.*

SCHORL is a dark-coloured stone, generally violet, black, or green, very seldom white, sufficiently brittle, and capable of giving fire with steel. It melts easily into a black opaque glass: it is, according to Bucquet, a combination of iron and aluminous earth. Bubbles have been found in the interior part of schorls, similar to those in the flags of glass-houses.

• Its origin is not very well known. Some people think it a volcanic product, because it is often found in places which have felt the ravages of fire; but it is likewise found among matters which have been long exposed to the action of water.

Species.

1. Violet schorl, in crystals.
2. Violet schorl in fibrous masses.
3. Black schorl, in prisms of 4, 6, 8, or 9 sides, with

with pyramids of 2, 3, or 4 faces, like the violet schorl.

4. Black schorl, in masses.
5. Green schorl, in lamellated masses.
6. White schorl, somewhat blueish.
7. Electric schorl, of a yellowish red, tourmaline.

Genus IV. *Macles*.

UNDER this name we comprehend a genus of stones, of a prismatic form, opaque, dirty-coloured, and generally of a regular figure. By analysing them M. Bucquet found them to be of a nature nearly resembling that of schorls, namely, a compound of iron and aluminous earth.

Species.

1. Tetrahædral macle, the section of which exhibits the figure of the cross. It is found in a kind of hard deep blue schistus of Brittany, to which it adheres strongly: it is very brittle, and when broken exhibits on its transverse section two blueish lines, cutting each other in the form of a cross. Sometimes the middle of the prism appears to be full of a matter resembling that of a gangue.
2. Stones of the cross; hexahædral prisms, articulated and crossed in the middle like the arms of a cross; these are found in the leaves of yellow mica; the two arms never cross each other at right angles.

Genus V. *Trap.*

TRAP is an hard stone fine grained, of a foliated fracture, and angular, like the steps of a ladder. Its colour is a deep green, approaching to black, often inclining to the colour of ochre ; it is very ponderous, and gives fire with steel. It melts into a blackish glass, and is always covered with a kind of crust softer than itself. It is a compound of aluminous earth and iron : According to Bucquet iron exists in it, in the proportion of twenty-five pounds to the quintal, so that it might be considered as an iron-ore. M. Daubenton thinks it a schistus containing quartz in sand. There is only one kind of trap known,—that which we have described.

Genus IV. *Azure Stone'; Lapis Lazuli.*

THIS stone is classed along with the preceding genera, on account of its colour, the fineness of its grain, and the quantity of iron which, from an analysis, it appears to contain.

Species.

1. Oriental azure stone.
2. Azure stone, of a pale blue, and often purplish.
3. Armenian stone, clouded with white and pale blue.

The azure blue used in painting, which is one of the most fixed and permanent colours known, is a preparation of this stone.

Genus VII. *Fusible Crystal Gems.*

M. BUCQUET, in consequence of observing the differences of the various kinds of gems, or precious stones as to chemical properties, was induced to arrange them separately under those divisions and orders to which they seemed most properly to belong. Those which we are going to introduce in this place are evidently compounds. Bergman found them to consist of various substances, such as siliceous and aluminous earth, lime, and iron; all of them are fusible, and composed of laminæ. Their fracture is lamellated.

Species.

1. Aqua-marina.
2. Emerald.
3. Crysolite.
4. Ruby.
5. Vermilion, or Bohemian garnet.
6. Garnet.

Genus VIII. *Volcanic Crystals.*

UNDER this genus Bucquet comprehended all such stones as are of a regular form, transparent, coloured, and similar to crystal gems, but possess not the hardness or brilliancy of these last. They are found in cavities lined with small sparkling particles of the same nature, agglutinated together. They are met with in the neighbourhood of volcanoes. We admit three species of them.

Species

Species.

1. Volcanic chrysolite; polyhædral crystals of a golden green.
2. Volcanic hyacinth, polyhædral crystals of an orange yellow.
3. Volcanic garnets. These strongly resemble single garnets; but they are irregular, and, as well as the two foregoing species, scattered among brilliant lavas.

Genus IX. *Pumice Stones.*

Most pumice-stones appear to be a collection of various threads wound up together, nearly like yarn on a reel. The pumice-stone is really a combination of various substances which have been reduced to fusion by volcanic heat.

Pumice-stones may be divided into four species; each which has many varieties.

Species.

1. White fibrous pumice-stone.
2. Coloured fibrous pumice-stone.
3. Light cellular pumice-stone.
4. Compact cellular pumice-stone.

Genus X. *Volcanic Glass.*

THE glass melted and discharged by Volcanoes is a mixture of earthy and saline matters, coloured with

iron or some other metallic substance. It is actually a natural chemical combination effected in the dry way.

Species.

1. Greenish cellular glass.
2. Blackish cellular glass, or in agglutinated threads.
3. Black glass, very fine and transparent; Iceland agate; lapis obsidianus of the ancients.

D I V I S I O N III.

Mixed Earths and Stones.

THE characteristics of the stones of this division are easily distinguished. We can discover merely by inspection, of what different matters they consist; and the more readily if we compare them with the stones of the two foregoing divisions. We formerly observed, that, in order to analyze them, it is first necessary to divide the various substances with an hammer; after this operation is performed, they are found to consist of simple united with compound stones. If these mixed stones be exposed unbroken to the action of fire, they will melt with more or less facility into a party-coloured glass, the nature and colours of which will be according to those of the matters of which it is composed.

These stones appear to have been formed by the union of the several substances of which they consist, effected either by fire or water. On account of this circumstance, Bucquet subdivided this third division into

two

two orders, as well as the foregoing. His first order comprehends mixed stones formed by water: the second, such as owe their composition to fire. As this subdivision is authorised by many more facts than that of the second division, we shall follow it with more confidence.

ORDER I. EARTHS and STONES Mixed by WATER.

Genus I. *Petro-flex*, or *Rockstone*.

By this name naturalists denote a stone of an intermediate hardness between soft stones and flex. M. Daubenton ranks it among the vitreous stones, because it scintillates with steel, and its fracture is vitreous, though sometimes rather scaly. Petro-flex has a kind of faint or half transparency like wax. It is dusky and destitute of brilliancy, and has even somewhat of the appearance of tallow; it is fine grained and very compact; it is found in large masses: it sometimes displays layers variously shaded, disposed one over another. The chemical characteristic by which M. Bucquet distinguished it, was its disposition to melt by fire into an opaque glass. It is far from being so easily discoverable to be a mixture as the following genera; it seems to possess the characteristics of compound stones *; and

R 2

for

* I must here observe, that these characteristics of stones, derived from the manner in which they are affected by fire, are founded on experiments made by M. Bucquet, in conjunction with the Duke de Rochefoucault, in an excellent furnace for fusion, constructed on purpose in the laboratory in which that illustrious cultivator of che-

for this reason we rank it at the head of the third division : it forms a kind of intermediate step between this and the foregoing.

The form of its layers, the matters which they often contain, and still more the masses in which it is accumulated in the bowels of the earth, show plainly that it owes its origin to water.

Species.

1. Grey petro-filex.
2. Reddish.
3. Greenish.
4. Brown.
4. Black.
6. Spotted.
7. Veined.

Genus II. *Pudding-Stone.*

PUDDING-STONE is a mixture of flints united by a cement of a different nature. That cement is either gritty or argillaceous, or ochreous; sometimes it is hard, and resembles filex.

Its formation is by no means equivocal ; it is owing to water. These stones are always found either on the sea-shore, or in places which have been once covered with water, and afterwards left dry.

Species

mistry prosecutes so many researches for the improvement of the science. I have re-examined most of the results of these experiments, which it is to be hoped will be one day communicated to the public: they will confirm the fine series of experiments made by M. D'Arcet; and will add to them a number of facts, serving to support Bucquet's arrangement of stones.

Species.

1. Sandy pudding-stone *.
2. Ochrous.
3. Argillaceous.
4. Siliceous.
5. Agatified ; susceptible of the finest polish.

Genus III. Granite.

GRANITE is formed by the union of smaller or larger fragments of three different stony matters. These are quartz, feldt spar, and mica.

On account of the quartz and feldt-spar which it contains, it gives fire with steel : its fracture is irregular and coarse-grained : it is fusible, but in various degrees, according as the three component matters are proportioned in the composition. It is susceptible of a finer or an inferior polish according to the fineness of its grain and the hardness of its principles. Some species of it suffer alteration, and waste away by the action of the external air. This last phenomenon enables us to distinguish ancient from modern granite. It has been subdivided into many species : But we shall reduce them all to the following †.

R. 3

Species.

* I have observed some of these in the very act of forming ; while they were, yet, soft and flexible, but, tough, and sufficiently cohesive. —H.

† The natural history of granites has been much studied by modern naturalists. M. Saussure, in his *Voyage des Alpes*, has communicated a number of new and important facts on this head. Granites are not invariably formed of a mixture of those three stones. Some of them, instead of mica, contain ichorl ; others contain both ichorl and mica at the same time. A mixture of quartz and feldt-spar, with

Species

1. White granite.
2. Grey.
3. Red.
4. Brown.
5. Green.
6. Black.
7. Dirty and friable granite, having suffered alteration by the action of fire.

Genus IV. *Porphyry*.

PORPHYRY is a stone speckled with spots on a ground of red, or some other colour. It produces abundance of sparks when struck with steel.

It differs from granite in being harder and susceptible of a much brighter polish : it seems to consist of feldspar and schorl, united by a quartzose cement.

The paste which constitutes the ground of porphyry is of a very fine close grain ; the other fragments united in it are generally much smaller than those of granite. This stone is fusible into a coloured glass. All the species of porphyry may be reduced to the following seven.

Species

1. Red porphyry, with large spots.
2. Red porphyry, with small spots.
3. Green porphyry, with large spots.
4. Green porphyry, with small spots.

Species

third substance, constitutes *granitine* : quartz and schorl compose *granitello*. See an account of these particulars in Saussure's *Voyage dans les Alpes*—F.

Species.

5. Black porphyry, with large spots. †
6. Black porphyry, with small spots.
7. Coarse porphyry, of a dirty red, almost without spots, nearly of the same nature with sand-stone.

Genus V. *Ophites, or Serpentine.*

PLINY gave the name of *ophites* to a kind of stones spotted like a serpent's skin. Bucquet considered these as a kind of porphyry, but harder, of a more ancient formation, and having their component parts much more intimately united than the other kinds. They have likewise received the name of *serpentine*, or *hard serpentine*. On comparing this stone with porphyry, it appears that they are both composed of a quartzose paste, with feldt-spar and schorl; but that in serpentine the fragments of feldt-spar and schorl are large and rhomboidal, while in porphyry they are very small.

Serpentine gives fire with steel; its fracture is fine and half scaly; it melts in the fire.

The following are most of the species of serpentine which we have had occasion to see.

Species.

1. Ophites of a deep green ground, with large white spots.
2. Dark green ophites, with oblong spots of a paler green.
3. Ophites resembling the preceding species; its spots very small, and scarcely visible: Many

Species.

savage nations use it for money : it has received the name of *thunder stone*.

4. Brown ophites, with irregular oblong spots of a rose-coloured white.

We are almost entirely ignorant of the circumstances of the formation of ophites. We know not even whether it be owing to fire or water. But as they resemble porphyry, we have for this reason placed them immediately after that genus.

ORDER II. EARTHS and STONES Mixed by FIRE.

Continuation of the Volcanic Products.

THE origin of these substances is well known ; they are never found but in the neighbourhood of volcanoes, or in places where volcanic fires have formerly existed. Besides, they possess all the characteristics of products of fire. These, together with the compound stones above described, will form a complete list of volcanic products.

We include not under this name all the matters which are found near volcanoes. Many of them are not altered by fire, such as most of the stones above described, more especially granite, clay, &c. as well as many saline substances, together with calcined, melted, sublimated, and vitrified matters. They exhibit nothing very remarkable, and were we to describe them here, it would occasion an unnecessary repetition. We shall in another place take notice of their existing in the neighbourhood of volcanoes, and of the alterations produced on them by subterraneous fire.

Genus I. *Volcanic Asbes.*

THE name of *volcanic asbes* has been improperly applied to a kind of pulverized earthy matters of various kinds, which are found in the neighbourhood of volcanoes. They appear to be composed either of a mixture of substances discharged from the volcano, or of substances altered by the action of air and water. Bucquet thought them to be combinations of iron and clay. They are generally attracted by the magnet. We know only two species of them.

1.

1. Rapillo, a pulverized matter, of a blackish grey, which is found round the edges of volcanic craters.

Rapillo contains garnets and schorls, the form of which is still discernible, though their angles have been softened and incruited by some matter in fusion.

2. Puzzolana. This substance has received its name from the town of Puzzoli, where it has been made use of since a very remote period : it is an argillaceous earth impregnated with iron, and variously coloured according as it contains a greater or less proportion of the metal. There is grey, black, yellow, red, and brown puzzolana. It melts by fire into a black enamel. It is used to compose a kind of cement or mortar, which possesses the property of becoming hard in water. M. Faujas de St Fond found some of it in Vivarais. He thinks that it is formed

teration and attrition of porous lavas, and even of basaltes. That philosopher, in his researches on the nature of puzzolana, gives an account of the processes necessary for building with it, both under water, and where it is to be exposed only to the action of the air.

Genus II. *Lavas.*

THIS name is given to matters which have been melted and half vitrified by volcanoes. They are usually scattered over the sides of mountains, the interior parts of which are inflamed over with volcanic foci. They issue from the craters of volcanoes in burning streams, which sometimes overflow a wide extent of country, carrying destruction and desolation wherever they direct their course. So considerable is their bulk, and so intense their heat, that they cool but very slowly, and are not quite cool till after several years. In cooling, they crack and separate into masses, which are sometimes of a regular form : and this seems to be the origin of basaltes. In cabinets of minerals there is a great variety of these stones. They generally consist of a grey paste, of a lighter or a deeper shade ; in grain and hardness subject to great varieties ; with crystals or irregular fragments of schorl, garnet, glass, zeolite, &c. interspersed ; which makes a true mixture. It is impossible to point out any certain general properties of lavas ; for they all differ from one another in grain, cohesion, hardness, colour, composition, &c. They are all in general very fusible, and afford a kind of blackish enamel, like volcanic glass. M. Cadet found them to contain iron, copper, and siliceous and aluminous earth.

Bergman

Bergman believed them to consist of siliceous, aluminous, and calcareous earths, with a mixture of iron. Many lavas, and more particularly those which are the most compact, possess the property of acting upon the magnetic needle.

Species.

1. Soft lava of various colours, containing crystals of black schorl.
2. Soft lava of various colours, containing crystals of green schorl.
3. Soft lava of various colours, with crystals of white schorl.
4. Reddish lava, with blackish crystals.
5. Yellowish saline lava.
6. Soft lava, with garnet crystals.
7. Porous lava, of a changing lustre (*Fr. Chatoyant.*)
8. Porous grey lava, volcanic stone.
9. Soft blackish lava, with white crystals.
10. Grey lava, somewhat compact, with duodecahedral, opaque crystals, or garnets altered by fire.
11. Ancient lava, very compact, of a blackish grey, and speckled with spots of a deeper colour.

Genus III. Basaltes.

THERE is nothing more inaccurate in the writings of naturalists, than their descriptions of basaltes. Some have confounded both schorls and garnets with this substance. There is no where to be found an accurate definition of the word *basaltes*. Some consider them

as products of volcanoes; others think them to be formed by water. The experiments and observations of Messieurs Desmarets and Faujas de St Fond, induce us to prefer the former of these opinions. Regularity of form, absolute opacity, and a considerable degree of hardness, such as that it gives fire with steel, a grey ashy colour, and an evident mixture of schorls, or small fragments of vitrified matter, of a deeper colour than the mass through which they are interspersed, may be considered as the distinctive characteristics of basaltes. They are likewise fusible.

Among this genus there are stones of enormous bulk, and collected in vast masses, which appear to have been formed at some very remote period in antiquity. Such are, 1. The columns of the Giant's Causey in the county of Antrim in Ireland. 2. The rock of Pereneire near St Sandoux in Auvergne, which is very accurately described by M. Desmarets. There are others regularly crystallised in small prisms of three, four, or five faces, &c.: their form, size, and disposition, are extremely various.

They are usually arranged in regular order, one beside another. No analysis of them has yet been made from which any thing could be determined concerning their nature. They seem to be nothing but lavas apparently crystallised, in consequence of the cracks which run through them in all directions while they are cooling*. Their arrangement and amazing varieties

* One theory which has been received concerning the formation of basaltes, is, that when a stream of lava pours into the sea, the impulse of the water causes it to contract and split into regular figures. But

rieties give considerable weight to this opinion: it likewise appears, that water insinuating itself into the chinks, deposits in them different kinds of earth, and alters the corresponding sides of the basaltic columns: and this seems to be the cause that produces the yellow or brown crusts with which they are covered.

Species.

1. Basaltes in very long polygon prisms, not terminating in regular pyramids.
2. Basaltes in short truncated prisms, of three, four, five, or seven faces.
3. Basaltes in short polygon prisms, terminating on the upper end in a concavity, at the lower in a convexity; articulated basaltes.
4. Small basaltes, quadrangular, triangular, &c.; formed by the fracture of the larger columns, and united in the same group with them*.

Genus IV. *Scoriæ of Lavas.*

The melted matter of which lavas consist is a mixture of various heterogeneous substances, differing in density.

But the ingenious M. Houel, in his *Voyage Pittoresque, &c.* shows this theory to be inconsistent with facts. He proposes another, in which he ascribes the formation of basaltic columns to the heterogeneity of the matters of which lavas are composed. An ingenious theory! but not sufficiently confirmed by facts.—H.

* For the history of these stones, and all the other products of volcanoes, see an excellent work entitled *Mineralogie des Volcans, par M. Fajjas de St Fond. Paris, 1784.*—F.

Of all the above species of basaltic columns, there are specimens to be seen in the *King's Park*, near Edinburgh.—H.

density and gravity. As it is slowly cooled, these several substances are separated, according to their gravities. Hence the scorïæ of lavas. These are spongy substances which have not been so thoroughly melted as the lava, and whose levity raises them to the surface of the mass. In other respects they appear to be of the same nature with lava ; the only difference being, that they are a more imperfect mixture. Scorïæ, as well as lavas, are found to contain schorl and garnet crystals.

Species.

1. Ponderous volcanic scorïæ, of a compact texture.
2. Black cellular volcanic scorïæ.
3. Black spongy volcanic scorïæ.
4. Black volcanic scorïæ, twisted like a rope.
5. Yellow ochreous volcanic scorïæ.
6. Reddish volcanic scorïæ.

The two last species plainly appear to have suffered alteration from the contact of air, water, and acid vapours.

Such was the classification of earths and stones which Bucquet thought proper to adopt in the years 1777 and 1778. Great progress has since been made in the chemistry of mineralogy. Stones are now analysed in almost every laboratory. Messrs Bayen, D'Arcet, Monnet, de Morveau, Sage, Mongez, and Pelletier, in France ; Scheele and Bergman in Sweden ; Achard, Bindheim, and Hupfch, at Berlin ; de Saussure in Switzerland ; Woulfe, Withering, and Kirwan, in England, have examined a great number of earths and stones : and in consequence of these analyses, the classification

lication of earths and stones must undergo a considerable change. Two of those chemists have therefore published new systems of mineralogy, in which their arrangements are founded on the nature of the component principles of minerals. But their methods are totally different from that of Bucquet, who sought to associate exterior characteristics with chemical properties. Bergman and Kirwan have paid no regard to physical qualities; the nature, the quantity, and the proportion of the component principles are the particulars on which they found their arrangements. Their system, though it may contribute greatly to the advancement of chemical knowledge, cannot teach us to distinguish stones by their appearance and sensible properties. It was therefore absolutely necessary to give, as we have done, some physical method, before entering on the examination of these systems. The one throws light on the other; and they may thus be equally useful to the student of mineralogy.

§ II. BERGMAN'S *Chemical arrangement of Earths and Stones* *.

BERGMAN, after showing that external properties, if judiciously selected, may be *of use* in forming a classification of minerals, but are not of themselves *fully adequate* to that purpose, establishes his principal divisions of

* This section is an extract from Bergman's work, published in French, by M. Mongez, under the title of *The Mineralogist's Manual*, &c. F.—There is an English translation of it by Dr Waring.—H.

of classes and genera on the composition and intimate qualities of those bodies. Every mineral is arranged by that principle which is the most powerful, or the most copious in its composition : all minerals, or fossils, are in this system divided into four classes ; salts, earths, bitumens, and metals. We shall here take notice of none but the earths.

Bergman acknowledges five different kinds of simple earth ; terra ponderosa, lime, magnesia, clay, and siliceous earth *.

He first examines each of these as pure earths, though none of them is ever found such in nature : he observes, that these five earths combine into twenty different species, ten of two, six of three, three of four, and one of the whole five. But he ranges among the species of earths all such of their combinations with acids as are not soluble in one thousand times their own weight of boiling water ; and those species are thus increased to a vast number. Besides, two compound earths, though made up of the same component principles, may differ widely as to the proportion in which these principles exist in them ; even so much as to be essentially different in their nature. These are the grounds on which Bergman and his commentator the Abbé Mongez, have distinguished earths into different species,

* Three of these five kinds of earth appear plainly to possess saline properties, namely, *Larytes* or ponderous earth, magnesia, and lime ; and we therefore reserve the history of them to the second part of the work. Bergman, whose intention was to divide stones according to their principles, was obliged to rank them among the earths, because they are often united with each other. Many of the substances which that illustrious chemist has placed among stones, come in our method to be considered as salts.—F.

species; for Mongez has made considerable additions to the labours of the Swedish chemist. The following are the species into which they divide each of the primary earths.

Ponderous Earth.*

Species.

- I. Pure ponderous earth. This is nowhere to be found in nature; it is obtained, as we shall afterwards see, by decomposing ponderous spar.
- II. Aërated ponderous earth; a combination of terra ponderosa with the aërial acid. This compound has not hitherto been found in nature: Bergman thinks that it may exist in water in a state of solution†.
- III. Vitriolated ponderous earth; ponderous spar: a combination of ponderous earth with the vitriolic acid. Abundance of this substance is found in mines. The Bologna stone is a variety of it.
- IV. Vitriolated ponderous earth, containing petroleum, mixed with selenite, alum, and siliceous earth; the hepatic stone of Cronstedt. This is a bright yellow, brown, or black

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sparry

* We shall here follow the denominations of Bergman. It will be easy to refer the ancient names both of earthy bases and of the acids united with them, to the new and methodical denomination, which we shall give those bodies in the history of saline matters. See the end of this volume, and the second.—F.

† A natural compound precisely of this species has been found in England since the death of Bergman. See the extract from Kirwan's Mineralogy.—F.

sparry substance; strong smelling, and not effervescent with acids. A quintal of this natural compound contains, according to Bergman, 33 parts of siliceous earth, 29 of pure terra ponderosa, and 5 of clay, beside lime, water, and vitriolic acid.

Lime.

Species.

- I. Pure or quick-lime. Bergman knew not whether this substance existed in nature.
- II. Aërated lime; chalk, or calcareous earth; a combination of lime with the aërial acid. It often contains marine salt of magnesia, calcareous marine salt, clay, and siliceous earth or iron. In the bowels, or on the surface of the earth, it constitutes lac lunæ, congelations, calcareous stones, marbles, calcareous spars, concretions or stalactites, &c.
- III. Bituminous aërated lime, or lime impregnated with petroleum; swine-stone. It is found in France at Villers-Cotterets, Plombières, and Ingrande in Anjou; at Rattwik in Dalmecarlia, Kinekulle in Westrogothia, Krasnasele in Ingermania, in Portugal, in Sweden, &c. If violently rubbed, or heated, it diffuses a fetid smell, which sometimes affects the nostrils in the same manner as cat's urine; and some authors have therefore given it the name of *lapis felinus*. It effervesces with acids, decrepitates, and loses its smell and colour in fire. When distilled

series.

tilled in large quantities, it affords, 1. A fetid liquor, which turns the syrup of violets green, and effervesces with acids; 2. A blackish oil, of a strong smell, resembling that which is obtained from pit-coal; 3. Concrete volatile alkali. The residue contains a little marine salt. This substance owes its peculiar properties to the bitumen mixed with it.

IV. Fluorated lime; fluor mineral, or vitreous spar.

A combination of lime with the spathose or fluoric acid, with a mixture of clay and siliceous earth, and a little of the marine acid.

V. Lime saturated with a peculiar acid, probably metallic *; ponderous stone; Swedish *Tungsten*. This is the weightiest of all stones. It is found in small yellow or red grains in the mines of Bastnaes, near Kitterhute in Westmania; at Marienburgh and Altenburgh in Saxony; it is sparry, bright, and whitish. It is often confounded with white tin ore. It scarce yields to the action of fire, and is vitrifiable only at the surface: it is not soluble in boiling water; the vitriolic acid separates the lime: by dissolving it in volatile alkali, precipitated by the nitrous acid, a white powder is obtained, which is the peculiar acid discovered by Scheele. In order to recognize and distinguish it from other stones, we must first reduce it to powder, and then pour upon it a

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* Found to be so. See Scheele's Essays, and De Lavoisier's *Essai sur la combustion*, both translated into English.—H.

Species.

due quantity of the nitrous or of the marine acid. This mixture, when gently heated, assumes a fine yellow colour. (See *Le Journal de Physique*, 1783, tome 22.)

VI. Aërated lime, contaminated * with a small mixture of muriatic magnesia, or marine salt of magnesia.

VII. Aërated lime, contaminated with clay; false marl.

VIII. Aërated lime, contaminated with siliceous earth. Some hewing stones and marbles give fire with steel, on account of the fragments of flint or quartz which they contain.

IX. Aërated lime, contaminated with a mixture of argillaceous and siliceous earth; perfect marl.

X. Aërated lime, contaminated with iron and manganese: false white iron ore; black and dusty, or hard, red, or whitish. The mines of Hallefors exhibit these varieties †.

Magnesia.

I. Pure magnesia. This is always a product of art.

II. Aërated magnesia, dissolved in water saturated with aerial acid.

III. Aërated

* The word contaminated, *inquinatus*, is used by Bergman to denote the mixture of two or more earths, when no real combination takes place. We shall therefore sometimes substitute the word *mixed* in its place.—F.

† All these species are saline substances, which will be described in the history of salts.—F.

Species.

III. Aerated magnesia, mixed with filiceous earth.

It scintillates and effervesces.

IV. Magnesia, intimately combined with clay and filiceous earth ; steatites, Briançon chalk, soap-stone, lapis ollaris, serpentine, lapis nephriticus.

V. Magnesia, combined with a considerable portion of filiceous earth, and a smaller quantity of calcareous and argillaceous earth, and contaminated with calx of iron. Asbestos ; mountain cork ; mountain leather ; amianthus. Bergman found a quintal of amianthus to contain 64 parts of filiceous earth, $18\frac{1}{7}$ ths of magnesia, $6\frac{2}{8}$ ths of lime, 6 of vitriolated ponderous earth, $3\frac{1}{8}$ ths of clay, and $1\frac{1}{7}$ th calx of iron ; a quintal of asbestos afforded 67 parts of filiceous earth, $16\frac{4}{7}$ ths of magnesia, 6 of clay, 6 of lime, $4\frac{1}{7}$ of calx of iron.

VI. Magnesia mixed with argillaceous and filiceous earth, and with pyrites ; a kind of ore of alum described and analysed by M. Monnet, (*Syst. de Mineralogie, genre 9. page 161*).

VII. Magnesia mixed with argillaceous and filiceous earth, pyrites, and petroleum ; magnesian aluminous schistus.

Clay.

I. Pure clay. It is precipitated from alum by aerated volatile alkali.

II. Clay mixed with filiceous earth. Porcelain earth ; Chinese kaolin. Solid clay from Saint-

Species.

Iriez in the Limoufin, from Japan, and from Saxony. Pulverulent clay from Westmania, Boferap, and China. These earths are often mixed with mica. Clays for potteries and delft-ware are coarser, but of a similar nature.

- III. Clay mixed with iron and siliceous earth. Boles or bolar earth, grey, yellow, red, brown, and black. These, when washed, become terræ figillatæ. Common clays, of a green, blue, or red colour, are of this species.
- IV. Clay mixed with siliceous and calcareous earths. Argillaceous marl ; pipe clay ; agaric mineral or fossil.
- V. Clay mixed with siliceous and magnesian earth. Lemnian earth ; fuller's earth ; soap-stone ; smectites. Bergman obtained from Lemnian earth, Hampshire clay, and English fuller's earth, a considerable quantity of siliceous earth, about $\frac{1}{3}$ th of clay, and as much aërated lime, with $\frac{1}{8}$ th of aërated magnesia, and the same quantity of oxide of iron. He gives to these earths the generic name of *litbomarga*.
- VI. Clay contaminated with sulphur and vegetable alkali : alum ore of Tolfa and Solfaterra. Bergman takes it to be a volcanic product.
- VII. Clay mixed with siliceous earth, pyrites, and petroleum ; aluminous schistus. It is found in Italy, in the district of Liege ; in Sweden, and in Jemteland. Black crayons, such as those from Bechel near Seez in Normandy, and the ampelites, are of this species. Tripo-

species.

lis are of the species of aluminous schisti, more or less burnt. Such are those of Poligné in Normandy and of Menat in Auvergne.

M. Mongez comprehends under this species, those schisti which contain much clay, and more or less siliceous earth and bitumen. Most of them contain likewise a mixture of calcareous earth, and effervesce with acids. The proportions in which the component principles are mixed in these schisti are extremely various. Some of them are so bituminous, that they burn with flame ; others are full of pyrites, and effervesce in the air ; some again are excessively hard, and give fire with steel. M. Mongez admits five varieties : 1. Hard argillaceous schistus, or writing slate : 2. Soft argillaceous schistus, or slate for roofing houses : 3. Soft siliceous schistus, used in polishing metals : 4. Hard siliceous schistus, used for whetting razors ; scythe-stone : 5. Hard calcareous schistus, which makes an indifferent lime, such as that of Allevard in Dauphiny.

VIII. Clay combined with nearly half its weight of siliceous earth, a little aërated lime, and some oxide of iron ; crystal gems. Bergman's fine discoveries concerning the nature of crystal gems, which, from their excessive hardness and apparent inalterability, were formerly though not to be susceptible of a chemical analysis, have been confirmed by the experiments of Messrs Margraf, Gerhard, and Achard.

Species.

The following is the result of Bergman's analysis of the five crystal-gems, which are varieties of the species we are now considering.

	Clay.	Silic.	Lime.	Iron.	
Oriental emerald contains	60	24	8	6	} 100th parts.
Oriental sapphire -	58	35	5	2	
Saxon topaz -	46	39	8	6	
Oriental hyacinth -	40	25	20	13	
Oriental ruby -	40	39	9	10	

The means employed by this ingenious chemist for resolving stones into their component principles, though very ingenious are very simple. (See *le Journal de Physique*, 1779, tome 14. p. 268 ; tome 21. p. 56 et 101) *.

IX. Clay combined with a portion of filiceous earth, equal to more than half the weight of the whole mass, with a very small quantity of aërated lime and some iron ; garnet, schorl, tourmalin. In these stones the proportion of the iron varies. See the analysis of the Tourmalin of Tyrol, by M. Muller, *Journal de Physique*, tome 15. p. 182. ann. 1780.

X. Clay slightly combined with half the weight of the mass, or rather more, of filiceous earth, and a small quantity of lime ; zeolite. M. Mongez considers the azure stone, *lapis lazuli*, as a zeolite. M. Margraaf found a small quantity of gypsum, ready formed in the *lapis*.

* Or rather Bergman's E

species.

XI. Clay combined with a considerable quantity of siliceous earth and a little magnesia; talc, mica. The proportion in which the principles exist in this stone is not yet perfectly determined.

Genus V. *Siliceous Earth.*

I. Pure siliceous earth. This is obtained by melting white quartz with four parts of fixed alkali, dissolving the whole in distilled water, and precipitating the earth with an acid. The precipitated earth is then washed and thoroughly dried.

II. Siliceous, united with a very small proportion of argillaceous and calcareous earth: The several varieties of rock-crystal, of quartz, and of grit-stone.

III. Siliceous, united with argillaceous earth. Hydrophanes chalcedony, or *oculus mundi*: according to M. Gerhard of Berlin, this stone contains a greater quantity of clay than of siliceous earth. Opal: M. Mongez considers cat's eye, fish's eye, and girasol, as varieties of this stone. To these three he adds agate and its varieties; cacholong, carnelian, sardonyx, gun-flint, and jade. They have not as yet been analysed with sufficient accuracy.

IV. Siliceous earth united with clay strongly impregnated with iron; jasper. M. Mongez

considers the finople as a variety of the jasper.

V. Siliceous earth united with such a quantity of martial earth as renders it ponderous; false jasper. M. Mongez calls this stone a metallic quartz. He distinguishes it into the black coloured by iron, and the red-coloured by copper.

VI. Siliceous united with argillaceous earth, and a little lime; petrosilex. This stone sometimes gives fire with steel, and effervesces with acids. It melts in a strong fire.

VII. Siliceous earth united with clay, and a little magnesia; feldt-spar. It suffers a change of colour, and melts in the fire. Air does not decompose it. It gives fire with steel, and breaks at every stroke.

VIII. Siliceous earth, united with magnesia, aërated and fluorated lime, and a portion of oxide of copper and iron; prase, chrysoprase. Bergman gives the composition of this stone from an analyses of it by M. Achard.

I. A P P E N D I X.

BERGMAN, in his first appendix treats of mineral substances mechanically mixed or united, in such a manner that the principles of the mixture or composition may be at once distinguished by ocular observation. We shall mention none but mixtures of earths; such are the stones known by the name of rocks, *saxa*. M. Mongez, who has made considerable additions to what

Bergman had done on this head, distinguishes these stones or rocks into two genera. 1. The first, those whose parts are not united by any cement, but simply adhere by juxta-position. These are formed by the agglutination of a number of fragments. He distinguishes them into three species,—granite, gneis of Saxony, and horn-stone. 2. His second genus comprehends such mixed stones as have their parts incruited in a common cement; as is the case with the four species of porphyry, ophites, or serpentine, breccia, and pudding stone. We shall here give the varieties of these stones acknowledged by this naturalist.

L. GRANITE is a composition formed by the union of quartz, feldt-spar, mica, schorl, and steatites, mixed in various proportions; consisting sometimes of two of these substances, sometimes of three, and sometimes of four. Quartz is always the base.

Variety I. Granite of two substances; granitine.

- A. Quartz and feldt-spar.
- B. Quartz and schorl.
- C. Quartz and mica.
- D. Quartz and steatites.

Variety II. Granite of three substances.

Quartz, feldt-spar, and mica. This is the most common, the most plentiful, and the most varied of all.

- B. Quartz, mica, and schorl.
- C. Quartz, schorl, and steatites.

Variety

Variety III. Granite of four substances.

A. Quartz, feldt-spar, schorl, and mica.

B. Quartz, feldt-spar, schorl, and steatites.

II. GNEIS is a mixture of quartz in grains, and mica in a greater or less proportion, with a considerable quantity of clay or steatites, which constitutes the base of the stone. This stone is foliated like the schistus. Exposure to the air soon alters and wastes it down, because the clay absorbs moisture. Many varieties of the gneis are found on the Alps of Dauphiny.

III. HORN-ROCK is a compact stone, consisting of very minute particles of an earthy aspect, and exhibiting over its surface sparkling points of mica. When moistened or struck, it diffuses a clayey smell. It hardens in the fire like clays, and when exposed to a very strong heat, melts into a blackish scoria or a black glass. Its colours are extremely various. M. Mongez thinks the Swedish *trapp* a variety of the horn-stone.

IV. PORPHYRY seems to be composed of a fine hard paste of the same nature with red jasper, containing either irregular or crystalline grains of quartz, of white or reddish feldt-spar, and sometimes of green or black schorl.

V. OPHITES, or serpentine, is a species of porphyry, of a green paste, and greenish white spots. The spots of the ophites are generally oblong; whereas the porphyry are square or rhomboidal. This stone is a variety of this species.

VI. BRECCIA, from the Italian word *briccia*, a crumb or fragment. This is a mixed stone of a much later formation than any of the above, formed of the ruins of the primary mountains, of irregular worn pieces of flint, &c. united by a common cement. M. Mongez makes no specific distinction between breccias and pudding-stones; but gives to the latter a compound name, indicating the nature both of their fragments and of their cement. He distinguishes these stones into eight varieties: The calcareo-calcareous breccia, under which denomination both the breccia properly so called and the lumachello are included; the filiceo-filiceous breccia, or the pudding-stone*; the breccia consisting of calcareous and filiceous fragments, with a calcareous cement; the breccia with filiceous cement, and fragments of the calcareous and filiceous genus; the arenario-filiceous breccia,—of this variety is the grey stone of Chartres; the breccia with a cement and fragments of jasper; the breccia with a cement and fragments of porphyry; and the volcanic breccia.

II. APPENDIX.

Volcanic Products.

M. MONGEZ, with Bergman, divides volcanic products into such as are formed by fire, and such as owe

their origin to water. The last are nothing but earthy matters, which having been dissolved or suspended in water, are by it deposited in places adjacent to volcanoes, and among volcanic products: of this kind are the calcareous and siliceous incrustations, as well as the zeolites which are often found among volcanized substances.

M. Mongez divides the genuine products of volcanoes into three orders: 1. Earthy substances, but little altered by fire; such as calcareous matters, clays, garnets, hyacinths, schorls, and mica. 2. Earthy substances which have been burnt and calcined; such as volcanic ashes or rappillo, and puzzolana, the tufa, the peperino of the Italians, pumice-stone, and the white earth which covers solfatara. 3. Earthy substances which have been in a state of fusion, or lavas; and of these he admits several kinds,—the spongy lava, the compact lava, the lava in stalactites, and volcanic glasses. After these divisions, he mentions such earthy volcanic products as are of an uncertain origin. Under this order he reckons particularly volcanic schorls, and still more basaltcs, which he takes to be masses of trapp softened by the humid vapours of volcanoes, and slowly dried after these have ceased to exhale.

§ III. *Chemical Classification of Earths and Stones, by* *Mr KIRWAN.*

IN the year 1784, Mr Kirwan, a celebrated chemist of London, published a work on mineralogy; in which he gives a general classification of minerals on their chemical properties or combi

part of his work contains earths and stones. He gives insipidity, dryness, fragility, incombustibility, and insolubility, as the characteristic properties of these substances. With Bergman, he distinguishes five genera of simple earths,—calcareous earth, ponderous earth or barytes, magnesia or muriatic earth, argillaceous earth, and siliceous earth. From a chemical analysis, he arranges all known earths and stones under these five genera.

CALCAREOUS GENUS.

To this he refers twelve species.

Species.

- I. Calcareous earth, not combined with any acid; virgin lime of volcanoes. *Falconer on Bath Waters*, vol. i. p. 156, 157; *Monnet. Mineral.* p. 515.
- II. Calcareous earth, combined with aërial acid. Its varieties, which he arranges in two series, are transparent calcareous spar, opaque spar, stalactites, tophi, incrustations, petrifications, agaric mineral or ghur, chalk, limestone, and marbles. *Bayen, Journal de Physique*, tome ii. p. 496.
- III. Calcareous earth combined with the vitriolic acid, gypsum, selenite, or plaster*. He admits two series; the transparent and the opaque.
- IV. Calcareous earth combined with the sparry acid, fluor spar, petuntze of Margraf. Series

I.

- I. Transparent fluor spars : II. Opaque fluor spars.
- V. Calcareous earth combined with the acid of tungsten. Tungsten or ponderous stone. *Woulfe, Phil. Transf. 1779, p. 26. ; Scheele's Essays.*
- VI. Aërated calcareous earth, mixed with a discernible quantity of magnesia. Var. I. Compound spar, described by *Mr Woulfe, Phil. Transf. 1779, p. 29.* II. Creutzwald stone, analysed by *M. Bayen †, Jour. de Phys. tome xiii. p. 59.*
- VII. Aërated calcareous earth, mixed with a discernible quantity of clay. Var. I. Calcareous marl. II. Travertino, margodes, stony marl. *Ferber's Travels in Italy, p. 117, 119.*
- VIII. Aërated calcareous earth, mixed with a discernible quantity of ponderous earth ; barytic marl of Derbyshire.
- IX. Aërated calcareous earth, mixed with a discernible portion of siliceous earth. Var. I. Stellated spar. II. Calcareous grit ; hard free-stone, *Moilon. Monnet, Mineralogy, p. 116.*
- X. Aërated calcareous earth, mixed with a small quantity of petroleum. Swine-stone.

XL

† It would be superfluous to give here the proportions in which the several principles are united in these stones, as we will have occasion to mention them in the chemical history of salts. We shall give the proportions only in Mr Kirwan's two last genera, which we consider as genuine earths.—F.

Species.

XL. Aërated calcareous earth, mixed with a discernible quantity of pyrites; *pierre de St. Ambroix*, analysed by the *Baron de Servieres*, *Journ. de Phys.* tome xxi. p. 394.

XII. Calcareous earth, mixed with a discernible portion of iron. Var. I. Aërated calcareous earth impregnated with iron, *Rinman*, *Mem. de Stock.* 1754. II. Tungsten impregnated with iron, *Cronstedt*, *Mem. de Stock.* 1751.

To these twelve species of calcareous earth, Mr Kirwan adds six species of compound stones, in which calcareous earth predominates. 1. Mixtures of the simple calcareous species, such as selenite and chalk, vitreous spar and tungsten. 2. Compounds made up of the calcareous and barytic species. Of this kind is a yellow stone of Derbyshire, formed of chalk with small lumps of ponderous spar. 3. Compounds of the calcareous and magnesian species; white marble mixed with steatites, the *pietra telchina*, and the *verde antico*. 4. Compounds of the calcareous and the argillaceous species, of chalk and schistus; such as the green campan of the Pyrenees, the red campan, Florence marble, the griotte, the amandula, the cipolin of Rome (see *Bayen*, *Journ. de Physique*, tome xi. p. 499. 801, et tome xii. p. 51, 56, et 57.); of chalk and mica, as the cipolin marble of Autun, the macigno, the *pietra bigia*, and the *columbina* or *turchina* of the Italians. 5. Compounds of the calcareous and the siliceous species; scintillating marbles, marble with a mixture of lava. 6. Lastly,

compounds of calcareous earth, with two or more of the other genera ; such as calcareous porphyry, and the lime-stone mixed with mica.

BARYTIC GENUS.

Under this genus he reckons six species.

Species.

- I. Ponderous earth combined with the aërial acid.
A stone found by Dr Withering on Alston Moor in Cumberland.
- II. Barytes combined with the vitriolic acid. Ponderous spar.
- III. Barytes combined with the spathose acid.
This substance exists not in nature, but is a product of art.
- IV. Barytes combined with the acid of tungsten.
This is obtained in the same manner as the preceding.
- V. Aërated barytes, mixed with a discernible quantity of filex and iron. Bindheim.
- VI. Ponderous spar, mixed with filex, mineral oil, and earthy salts. Hepatic stone, white, grey, yellow, brown, or black.

MURIATIC OR MAGNESIAN GENUS.

Mr Kirwan reckons eight species of this genus, arranging under it both those earths and stones in which magnesia predominates, and those which, though containing more filex than magnesia, yet exhibit all the characteristics of the magnesian genus.

ries.

- I. Magnesia combined with the aërial acid, and mixed with other earths. Var. I. Mixed with filex; *spuma maris*. The Turkish tobacco-pipes, and the Canadian pipe, are composed of this substance. II. Mixed with calcareous earth and iron; olive-coloured and bluish earth near Thionville. III. Mixed with clay, talc, and iron; greenish yellow Silesian earth.
- II. Magnesia combined with the aërial acid, with above four times its weight of filex, and a small proportion of clay. Var. I. Steatites. II. Lapis ollaris.
- III. Aërated magnesia combined with filex, calcareous earth, and a small proportion of clay and iron. Var. I. Fibrous asbestos. II. Coriaceous asbestos; mountain cork.
- IV. Aërated magnesia, combined with filex, aërated calcareous earth, barytes, clay, and iron. Amianthus.
- V. Pure magnesia, combined with a quantity of filex, more than equal to its own weight, a third part of clay, nearly a third of water, and one or two tenths of iron. Serpentine, *lapis nephriticus*, Italian gabro.
- VI. Pure magnesia, combined with twice as much filex, and less than an equal quantity of clay. Venetian talc, Muscovy talc.
- VII. Magnesia combined with the sparry acid. This substance is not found in nature.
- VIII. Magnesia combined with the acid of tung-
sten.

sten. This substance is not known to exist in nature.

To these eight species, Mr Kirwan adds five others, compounds in which magnesia predominates. 1. Compounds of the several species of magnesia with one another; steatites and talc, Briançon chalk; serpentine with steatites or asbestos. 2. Compounds of the magnesian with the calcareous species; red or yellow serpentine, with spots of white calcareous spar, *potzovera*; the black is the *Nero di prato*, and the green the *verde di fuza* of the Italians. 3. Compounds of the magnesian and the barytic species; serpentines with spots or veins of ponderous spar. 4. Compounds of the magnesian and the argillaceous species; steatites mixed with clay, mica, or schistus. 5. Compounds of the magnesian with the filiceous species; serpentine veined with quartz, feldt-spar, or schorl,

ARGILLACEOUS GENUS.

Mr Kirwan reckons fourteen species of this genus.

Species.

- I. Clay saturated with the aërial acid; *lac luna*, according to Schreber's analysis.
- II. Clay combined with the aërial acid, and mixed with filix and water; potter's clay, pipe and porcelain clay, &c.
- III. Clay saturated with the vitriolic acid; embryo alum in scales like mica. *Baumé*.
- IV. Clay saturated with the marine acid; *main* embryo alum.

cia.

V. Clay combined with about one part and an half of filex, nearly one part of magnesia, and half a part of dephlogisticated iron; mica.

VI. VII. VIII. IX. Clay combined with siliceous earth, magnesia, calcareous earth, iron, or a bitumen; slate, blue schistus, pyritous schistus, bituminous schistus, and argillaceous schistus.

X. Clay combined with a little filex, magnesia, and calcareous earth, with a quantity of iron calx, nearly equal in weight to the clay; horn-stone, or *born-blende*.

XI. Clay combined with a quantity of filex equal to four times its own weight, with half its weight of calcareous earth, and somewhat more than its weight of iron; toadstone.

XII. Clay united to from twice to eight times its own weight of filex, half its weight of lime, and once or twice its weight of water; zeolite.

XIII. Clay united with four times its own weight of filex, and one third of iron; pitch-stone, lava.

XIV. Clay mixed with a discernible portion of red iron calx, and sometimes with steatites; red chalk.

To these Mr Kirwan adds six compound species in which the argillaceous genus predominates.

SILICEOUS GENUS.

This genus in Mr Kirwan's system, comprehends twenty-six species,

Species.

- I. Siliceous earth nearly pure; quartz, crystal sand.
- II. Siliceous earth, with one-fourth clay, and one-fortieth calcareous-earth; flint, gun-flint, See *Weigleb. Act. nat. Curios. t. 6. p. 408.*
- III. Siliceous earth, with from one-fourth to one-third clay, and from one-twelfth to one-fifteenth calcareous earth; petrosilex,
- IV. Siliceous earth, with one-third clay, and one-sixth or one-seventh iron calx; jasper.
- V. Fine siliceous earth, mixed in various proportions with iron and other earths; agate, opal, chalcedony, onyx, carnelian, and sardonyx. Precious stones of the second order.
- VI. Siliceous earth, with from an equal quantity, to nearly three times its own weight of clay, from a sixth part to an equal quantity of calcareous earth, and from one-eighteenth to an equal quantity of iron; ruby, topaz, hyacinth, emerald, sapphire. Precious stones of the first order.
- VII. Amethyst. The principles of its composition are not yet known.
- VIII. Siliceous earth, with one fifty-fifth of calcareous earth, a smaller quantity of magne

ecies.

fia, and a very small quantity of iron, copper, and sparry acid ; chrysophrase.

IX. Siliceous earth, with blue fluor spar, and a little gypsum ; *lapis lazuli*. M. Margraf found in it chalk, gypsum, filex, and iron. M. Rinman observed it to contain a portion of the sparry acid.

X. Jade. M. Kirwan conjectures it to consist of filex, magnesia, and iron.

XI. Siliceous earth, with clay, ponderous earth, and magnesia ; feldt-spar, petuntze, and Labrador stone. 100 parts of feldt-spar contain 67 parts of filex, 14 of clay, 11 of ponderous earth, and 8 of magnesia.

XII. Siliceous zeolite. This substance is found at Mæssiberg. It differs from the true zeolite in giving fire with steel, which the other does not ; and this property is a proof that filex is one of its principles.

XIII. Siliceous earth, with clay equal to more than a third part of its weight, and one-ninth of chalk, with no iron ; white garnet of Mount Vesuvius. 100 parts of it contain, according to Bergman, 55 of filex, 39 of clay, and 6 of chalk.

XIV. Siliceous earth with clay, chalk, and one-tenth of iron, garnet. Bergman says that 100 parts of this stone contain 48 of filex, 30 of clay, 12 of calcareous earth, and 10 of iron.

T 4.

XV.

Species.

- XV.** Siliceous earth, with a good deal of clay, nearly one-tenth of chalk, and a little iron and magnesia; schorl.
- XVI.** Bar schorl, German *Stangen schoerl*; found by M. Fichtel on the Carpathian mountains. It is found among lime-stone, is of a prismatic form, and gives a slight effervescence with acids. M. Bindheim obtained from 100 parts of this schorl, 61 of flint, 21 of chalk, 6 of clay, 5 of magnesia, 1 of iron, and 3 of water.
- XVII.** Tourmalin. The following are, according to Bergman, the proportions of the principles of the tourmalins of Tyrol, Ceylon, and Brazil.

	Clay.	Sil.	Cal.	E.	Iron.	
Tourmalin of Tyrol	42	40	12	6	} 100 parts.	
———— of Ceylon	39	37	15	9		
———— of Brazil	50	34	11	5		

- XVIII.** Basaltes, trapp. 100 parts contain, according to Bergman, 52 of siliceous earth, 15 of clay, 8 of calcareous earth, 2 of magnesia, and 15 of iron.
- XIX.** Rowly rag. A grey granulated stone, which heat renders magnetic and melts, and which in the air acquires an ochreous crust. 100 parts of it, according to Withering, contain 47.5 of siliceous earth, 32.5 of clay, and 20 of iron.
- XX.** Silex, clay, iron, and calcareous earth, melted together by volcanic fire.

ies.

1. Cellular lavas, improperly called pumice-stones. These have been very imperfectly melted. Bergman found them to contain from $\frac{4}{100}$ to $\frac{10}{100}$ of silica, from $\frac{1}{100}$ to $\frac{2}{100}$ of iron, $\frac{4}{100}$ or $\frac{5}{100}$ of pure calcareous earth; and the rest of the composition, clay.
2. Compact lavas. These have undergone a second fusion, and have therefore but few cavities. They sound when struck.
3. Vitreous lavas, or lava entirely melted into black, green, blue, &c. glass. M. Saussure, by melting together, more or less thoroughly, certain quantities of horn-rock, marl, and schistus, has produced imitations of these lavas. (*Voyage dans les Alpes*, p. 127).

XXI. Siliceous earth, united with about a tenth part of magnesia, and a very small portion of calcareous earth; pumice stone.

XXII. Siliceous earth, with less than its own weight of magnesia and iron; martial magnesian spar. Pisolite found at Sainte Maire, by M. Maret.

XXIII. Siliceous earth, with one third its own weight of aerated calcareous earth; Turkey stone. Oil hardens it.

XXIV. Siliceous earth, mixed with a little iron and calcareous earth. Rag-stone.

XXV. Quartz consolidated with less than its own weight of calcareous earth or clay, and a little iron; grit reducible to sand by pounding
 Var. I. Grit with a calcareous cement; of Fontainebleau
 with acids. II.
 With

Species

With an argillaceous cement. This variety does not effervesce. It is used for building, for whet-stones, and for filtering water, &c.

XXVI. Siliceous earth consolidated with semi-phlogisticated calx of iron; brown or black scintillating stone, which becomes red and exfoliates in the air. Semi-phlogisticated iron agglutinates earths; but iron, when very much calcined, possesses not the same agglutinative power. This fact has been demonstrated by Messrs Edward King and Gadd.

To these twenty-six species of the siliceous genus, Mr. Kirwan annexes six other species in which that earth predominates. The varieties which he includes under these species, are compounds frequently found in mountains of ancient formation. The English chemist draws this supplement to the siliceous genus from M. Saussure's observations on the Alps. Among these varieties are, the several kinds of granite, pudding-stones, granitellos, granitines, porphyry, gneis, variolite, &c *.

C H A P.

* Since the publication of the fourth edition of M. Fourcroy's work, Mr Kirwan has published a new edition of his Elements of Mineralogy, in which his system is greatly altered and enlarged.

In this edition he enumerates nine simple earths, the calcareous, the barytic, the magnesian, argill, the siliceous, the Scottish, the jargonie, the adamantine; but not without intimating a suspicion, that the four last may be modifications of some of the five first.

In addition to the *chemical characters* which he before employed alone in his arrangement of stones, he has now adopted from the illustrious Werner, the use also of the *external physical characters*, indicated by that naturalist.

The *external characters* which Kirwan here employs, are, *colour, shape, lustre, transparency, texture, cohesion, density, adhesion to the tongue or fingers, and general feel, colour of a streak, absorption or diffusion in water, smell, and taste.*

The *internal characters*, are, *relation to acids, changes operated in a low heat, fusibility and other changes in higher degrees of heat, phosphorescence, magnetism, electricity, and the results of a just analysis.*

He gives very ample tables of the fusibility of the simple earths, mixed in various proportions, in heats not exceeding 166°. of Wedgewood's pyrometer.

His primary genera consist of earths and stones having an **HOMOGENEOUS** aspect.

The species of the *calcareous genus*, are now augmented to the number of *thirteen*, and are all considerably altered in the descriptions of them, and in their arrangement in the table.

The species of the *barytic genus* are now reduced to *three*; barolite or aerated barytes; barytes combined with the vitriolic acid; and the liver-stone, or *lapis hepaticus*.

The species of the *magnesian, or muriatic genus*, are now increased to *twenty*.

The *argillaceous genus* is divided into *two classes*; the *first* comprehending argillaceous earths liable to moulder in water, and subdivided, not into species, but into *six tribes*; the *second* containing argillaceous stones not liable to moulder in water, and subdivided into *seventeen species*.

The species of the *siliceous genus* are now augmented to *forty-four*.

The *frontian or Scottish genus* consists of but *a single species*.

The *jargonie genus* has no species, save only the jargon of Ceylon.

The *Sydnæian* is not more diversified than the two last foregoing genera.

The *adamantine genus* has but the single species of adamantine spar, diversified into three varieties.

From the discrimination and history of these homogeneous earths and stones; Mr Kirwan next proceeds to examine **AGGREGATED stones**; which he defines to be "stones visibly involving two or more heterogeneous substances, either adhering together, or inhering one in the other." Of this character, he enumerates and describes granite, sienite, granatine, granitell, granilite, gneiss, shistose mica; porphyry, jasper porphyry, hornstone porphyry, pitchstone porphyry, obsidian porphyry, horn porphyry, petunse, petunse porphyry, clay porphyry, hornblende porphyry, trap porphyry, wacken porphyry, mullen porphyry, kragg porphyry, argillitic porphyry, novaculite porphyry, pitstone porphyry, serpentine porphyry, granite porphyry. sandstone porphyry, amygdaloid, pudding-stone; calcareous sandstone, argillaceous sandstone,

sandstones, siliceous sandstones, ferruginous sandstones, rubblestone, breccias.

After these follow the *derivatives*, which are defined as “seeming to participate of the nature of two or perhaps more heterogenous fossils, without, however, any visible separation of one from the other.”

In these appendices, Mr Kirwan, examines, 1. diamond, and 2. volcanic products; and 3 gives an account of the chemical analysis of earths and stones.

The second volume of this valuable work, in which the author promises to treat of saline inflammable and metallic substances, is impatiently expected by the public—H.



C H A P.

C H A P. IV.

Of the Chemical Analysis of Earths and Stones.

THOUGH, within these few years, the chemical analysis of earths and stones has been much more industriously prosecuted than at any former period, yet still it must be confessed, that our knowledge of their component principles is far from being sufficiently extensive or accurate, to be assumed as the foundation of methodical arrangement of them. Hence the diversity of the chemical classifications of these substances which have been hitherto offered to the public; and for this reason have we been induced to give an account of the different methods successively proposed by three celebrated chemists in the course of a very short period of time.

The chief advantage which has been gained from the various researches of late made into the nature and component principles of earths and stones, is the discovery of proper means for distinguishing these. The method of analysing these substances is not a little complex; and I mean to give only a general account of it in this chapter. In fact, as the student of chemistry, who has read only the foregoing part of this work, though acquainted in some degree with the phenomena of fire, air, and water, must be entirely

ignorant of the properties of saline bodies, which are so efficaciously employed in separating and examining the constituent principles of earths and stones; if we were here to speak of the use of solvents in analysing these matters, we should both deviate from that order and regularity which are necessary in laying down the elements of physical science, and likewise run the risk of becoming unintelligible: I shall therefore reserve a minute and particular account of the chemical decomposition of earths and stones by acids and alkalis to a different part of the work *, explaining here nothing but its general principles.

When we wish to discover the chemical properties of a stone or an earth, we must begin with a careful examination of its physical properties, its form, hardness, gravity, colour, &c. The extraneous substances, of which there is always a greater or a less quantity mixed with such bodies, must next be separated from it, so as that it may be purified from all mixture, by picking, washing, &c. A stone should be reduced to powder, or, if the expression may be allowed to the state of earth, before we attempt to examine its principles. The first trial that is made is generally with fire. A few ounces are exposed in a well-baked crucible of clay or porcelain, to the heat of a strong furnace, such as Macquer's; that of a potter's or a glass-maker's is still better for the purpose. It is to be observed of the crucibles used in this operation, that the argillaceous earth of which they are chiefly composed

has

* See the treatise on the *Analysis of Waters*, at the end of this work.
—F.

has often a considerable share in producing the alteration which the stony substance seems to suffer from heat : but we have no way of avoiding this inconvenience ; and indeed it becomes of little consequence in a comparative analysis of a great number of stones. Of late years, the use of the blow-pipe for treating mineral matters with fire, has been introduced ; and in the chemical examination of an earth or a stone, this instrument may be employed together with the above described means for decomposition. Those substances are exposed to the fire, either alone or several of them mixed together, or with a mixture of some saline matters to be afterwards described *. Lastly, they may be likewise treated with a machine for pouring vital air on coals, of which I have given a description in my *Memoirs de Chimie*, and which produces a heat that for intensity may be compared to the focus of a glass lens, such as that of the academy. These operations produce either a fusion more or less perfect, or some change of colour, consistency, form, &c. which is to be carefully described. The process must be farther carried on, by putting the stony matter into an earthen retort, fitted up with a receiver and a pneumato-chemical apparatus †, in order to collect whatever water and aëriform fluids may be disengaged. Matters which afford these products are properly salino-terrene substances, though they be considered as stones by naturalists ; yet,

* See Bergman's paper on the blow-pipe, with Mongez's notes *Manuel de Mineralogiste* ; or Cullen's English translation of Bergman.—F.—H.

† See a description of this apparatus under the article *Gaz* of the *Chemical Dictionary*, or in M. Sigaud d' *on the differ-*

yet, as they are often found mixed with genuine earths, it is therefore proper to mention here the general mode of examining them. The action of fire shows whether a stone be siliceous, aluminous, or mixed. But as most stones are of the latter kind, and many of them consist of several, some even of five or six, different substances united in various proportions, other processes are likewise to be employed for determining the principles of their composition. These consist in treating them with several acid and alkaline solvents, the successive application of which separates all the principles of which they consist.

The action of air, and of water in vapour, may likewise contribute to make us understand the nature and constituent parts of earthy and stony matters. Some of them suffer no alteration from these agents; others are divided, and gradually assume a new form, colour, and consistency. These phenomena belong chiefly to stones of a very compound nature, and containing much iron. Lastly, lixiviation with cold and warm water, shows whether they contain saline matters, however difficult it may be found to bring these to solution.

Such are the means by the use of which modern chemists have been able to determine the nature and the component principles of so great a number of earths and stones. I have here given but a very short and general account of them. In the history of saline matters, we shall give all those particulars concerning them which cannot be conveniently or advantageously introduced here.

SECTION

SECTION II.

CHAP. I.

Saline Substances in general; their Characteristics, Nature, and the Method of arranging them.

SALINE substances, of which there are a very considerable number, possess peculiar properties by which they are distinguished from those which we have hitherto been examining. The properties which have been employed by *chemists* as characteristics of saline matters, are such as leave their real nature somewhat uncertain: being common to many other bodies besides salts, they extend this class of substances far beyond its just limits. Taste and solubility in water, which have been always given as characteristics of saline substances, belong to many bodies which are not saline; as for instance, to all mucilages and animal matters. These two properties again exist in a very various and imperfect degree in several saline substances. *Naturalists* have not been more accurate in their definitions of salts: the transparency and crystalline form which many naturalists have considered as peculiar to them, belong equally to many other matters, especially earths, while some salts are quite destitute of them.

Macquer has, therefore, asserted, with great truth, that the true limits which divide saline matters from other classes of substances are not well known.

Yet as we *must* take *some* side, and form some determinate notions concerning the properties of these matters, we shall take a general view of them, before proceeding to the history of each particular salt.

We acknowledge as saline substances, all such as possess the greater part of the four following properties: 1. A strong tendency to combination, or affinity of composition: 2. A stronger or fainter taste: 3. A greater or a less tendency to solution: 4. Absolute incombuftibility. Before proceeding to consider each of these properties by itself, we must observe, that in proportion as a body contains more or fewer of them, and those in a greater or less degree, it is more or less of a saline nature. From this, however, we must not conclude, that matters possessing these properties but in a very faint degree are not saline. Were we to admit such a principle, we should expose ourselves to frequent errors; as it sometimes happens that two salts, which in a solitary state possessed these properties in a very low degree, afford still fainter indications of them after being combined. In such cases recourse must be had to chemical analysis, which, by separating the substances, will render their chemical properties more observable.

I. *Tendency to Combination considered as a Characteristic property of Salts.*

Most salts have a tendency to combine with many different substances. Among salts we find the most active bodies in nature, capable of forming an infinite number of combinations, by entering into union with others. Chemists have, therefore, always made most use of saline matters; some of which they have honoured with the names of *solvents* and *menstrua*. Yet this tendency to combination is far from being the same in all salts. Some of them possess it in so strong a degree, that they corrode and destroy, or dissolve whatever touches them, even vitrifiable and quartzose stones not resisting their attacks; such is the power of many of those pure salts that are known by the names of *acids* and *alkalis*. Others, though not possessed of such a force of combination, unite readily with many bodies. Finally, there are some among them, whose tendency to combination is but very trifling, and scarce superior to that of earthy matters. But the cause why, in these latter, the tendency to combination is so small, is, their being in a great measure saturated, as is observable of neutral salts. After this, we cannot well be surprised that salts are scarce ever found in a pure or solitary state in the bowels of the earth.

I. *Taste considered as a Characteristic of Salts.*

It has been always regarded as so essential a property of saline substances, that many philosophers

have considered them as the only bodies in nature possessed of this property, and the principle of all taste. Though this opinion be not demonstratively certain, as there are many bodies, such as metals, which have a discernible taste, though not saline, while, again, several saline substances have scarce any taste ; yet it must be acknowledged, that most salts possess the property of taste ; and this property is therefore to be considered as one of their leading characteristics. The taste of salts, like their other properties, is different in different species. In order to understand aright on what circumstances it depends, and whence the causes of its varieties, we must first endeavour to distinguish what constitutes the peculiar nature of this property. By taste, we usually understand an impression made on a certain organ which nature has given us for the purpose of distinguishing by it some material body, and from which we judge of that body as useful or noxious, and determine either to make use of it or reject it. It is therefore the action of the sapid body on the nerves of the tongue and palate of animals, which informs them that one substance may be of use, or another hurtful to them. But can this property of bodies affect only the nerves of the tongue ? will it not act with equal force on the whole nervous system ? Those who are acquainted with the phenomena of the animal œconomy, know that the action which constitutes taste or sapidity, must affect all the other nerves, and must always be proportioned to the sensibility of the subjects and the organs on which it operates. This idea of taste naturally leads us to think, 1. That this quality of bodies will make scarcely any impression on such parts of the body as have

but few nerves, or of which the nerves have but little sensibility, on account of their being covered ; as on the skin where they are defended by the reticular membrane and the epidermis. 2. That this quality of bodies will act with the most energy on those organs in which the nerves are largest, most numerous, and of a form the most proper for receiving an extensive contact, and a violent emotion from salts ; the epidermis being so thin as to leave the nerves almost naked. The superior surface of the tongue, the roof of the mouth, and all the inner part of the mouth in general, are susceptible of the sensation of taste, from a vast number of bodies which make no such impression on the less delicate sensibility of the other parts of the skin. 3. That bodies which have no taste and no power of affecting the skin, may notwithstanding this, act upon organs which are more delicate, and have nerves of greater sensibility, such as the stomach and the intestines.

Admitting these facts, we may distinguish tastes and sapid bodies into three classes, under which all the saline substances that we are to examine may be arranged. The first class comprehends such salts as have the strongest taste, and affect the skin in the most sensible manner. The impression of these salts is so powerful, that it occasions a very lively sensation of pain ; and where its action is continued for some time, it entirely destroys the organization and texture of the skin. This property is called *causticity*, and the salts which possess it are named *caustics*. The second class consists of salts which have a milder taste, and affect only the nerves of the organs through which we receive that sensation : these are

ther by names expressing the several impressions which they make on those organs ; such as bitterness, astringency, acidity, acridity, urinous taste, &c. To the third class we shall refer saline substances, the taste of which is sensible only to the stomach and the intestines ; but the number of these salts is very scanty.

Some observations are necessary on the mutual relations of these several classes of salts. It is first to be observed, that between those which possess the peculiar properties of any of the three classes in the weakest, and those which possess the same properties in the strongest degree, there are many varieties ; there are stronger and weaker caustics ; some instantly destroy the texture of organized substances, others require a considerable time to produce that effect. The same fact may be observed of bitter, astringent, or urinous salts, as well as of those which act only on the nerves of the stomach. Secondly, when we consider these varieties of the several classes, we are naturally led to think, that all tastes are but different degrees of the same property, from that of the strongest caustic salt to that of the saline substance, whose action is scarce sensible to the nerves of the stomach. This observation implies, that all tastes actually depend on the same cause, and participate of the same principle.

We cannot adopt an happier method of distinguishing the cause of taste, than to consider that taste which is the strongest of all, observe its phenomena, and attend to its action. Causticity must therefore be the subject of our consideration : a property which has always attracted the curiosity of chemists. Lemery, observing that very hot bodies were usually very caustic,
and

and that all salts possessing the property of causticity have been strongly heated before acquiring it, ascribed this property to the particles of fire lodged in caustic bodies. M. Baumé has implicitly adopted Lemery's opinion. Meyer, an apothecary of Osnaburgh, made a series of researches into the nature of caustic salts, and formed a very plausible theory, which was at first warmly embraced by a number of chemists, but is no longer mentioned with the respect which it once obtained. He attributed causticity to a principle which he considered as a compound of fire and a peculiar acid: this, in imitation of the ancient chemists, he named *causticum*, or *acidum pingue*. He traced it through its various combinations, as Stahl had done with phlogiston. But his system has the same defect with Stahl's; the existence of his *causticum* has not been demonstrated. Dr Black, by a series of experiments on the same matters which Meyer examined, has levelled the severest blow again *his* theory; proving, by rigid demonstration, that lime and alkalis, instead of deriving their causticity from a *fat acid* principle, become acid in consequence of losing a salt, to be afterwards mentioned under the name of the *Carbonic Acid*.

Macquer has undeniably been the most successful inquirer into the cause of causticity. The doctrine which he lays down on that article in his Chemical Dictionary is so plain, and supported by such conclusive facts, that we cannot refuse assenting to his opinion. After observing that caustic bodies destroy and corrode our organs, by entering into combination with the principles of which they are composed, he remarks, that in proportion as this combination takes place, the

caustic gradually loses its strength; and that it becomes absolutely destitute of causticity, when it has dissolved as much of the animal matter as its force and quantity are equal to. Thus the *lapis causticus*, or pure fixed alkali, gnaws and corrodes the skin when applied to it; but loses its corrosive and solvent power when it ceases to act on that organ. This salt really acts by a chemical power, for it exerts its force even on the insensible skin of a carcase; as M. Poulletier has shown by accurate experiments, and on all animal substances in general. Causticity therefore depends on tendency to combination; and the sensations with which it affects our organs are occasioned by the combination of the caustic with the matter of which the organs are composed. In the same manner a caustic loses its virtue in the laboratory, by combining with any substance with which it has a strong affinity; and in a word, the causticity of a body is always in the proportion of its tendency to combination. That salt which has the faintest taste is already saturated with some substance; and by separating it from that substance, we cause it to regain a taste, stronger or weaker, according as the separation is more or less complete. The whole history of saline matters concurs to support this opinion, as will appear in what follows.

§ III. *Solubility considered as a Characteristic of Salts.*

SOLUBILITY in water has been given by all chemists as one of the most eminent characteristics of salts; yet this property, like taste and tendency to combination, is subject to varieties. Some salts possess it in such a
degree,

degree, that without very long and refined processes, it is impossible to separate them entirely from water. Others are not so extremely soluble, and the degrees of their solubility may be precisely ascertained ; as, for instance, most neutral salts. Lastly, there are some saline substances, whose tendency to solution is so faint and indistinct, that they seem to differ more in nature from the other classes of salts than from earths and stones ; and all salts of this character have been by most naturalists considered as earths and stones. It is indeed extremely difficult to fix the precise limits between these two classes of mineral bodies ; and chemists have not as yet agreed in determining them. Mr Kirwan, in his mineralogy, seems to have adopted Bergman's opinion ; who thinks that all substances are to be considered as earths, which require more than a thousand times their own quantity of water to maintain them in a state of solution, while all such as are soluble in a smaller proportion of water, should be distinguished as salts. Were this proposition generally received among chemists, as I think it well deserves to be, that diversity of opinions and terms which has hitherto prevailed on this point might be avoided ; and they have a direct tendency to render the science more obscure and perplexing to beginners.

The relation which I have taken notice of, as subsisting between the taste and the solubility of salts, is exactly the same with that which subsists between taste and tendency to combination. The cause of these differences may be easily understood by observing, that when a salt is dissolved in water is a real chemical union of a salt with water, and must therefore d

with taste and tendency to combination. In fact, the more taste and solvent force a salt has, the more readily does it dissolve in water. This law holds invariably with regard to all saline matters, and even depends on their nature and essential properties.

§ IV. *Incombustibility considered as a Characteristic of Salts.*

It is more difficult to form a determinate idea of this fourth than of the three preceding characteristics of saline matters. No chemist has as yet considered these substances under this point of view. A number have even thought, that some salts, and among others nitre, are actually combustible.

In order to see clearly that this is a mistake, and that all mineral saline substances are absolutely incombustible, the student of chemistry must have a much fuller knowledge of the properties of those substances, than he can have acquired from perusing the foregoing part of this work. However, as we think this one of the most essential and important characteristics of salts, we shall here give a short view of the doctrine which we are induced to advance on this head, and which will be fully illustrated and inconvertibly established, in our particular examinations of saline substances.

It appears from M. Lavoisier's fine experiments, that many combustible matters form by their combustion, peculiar acids. Combustion, as above explained, is nothing but the combination of the base of vital air, or the oxygenous principle with combustible b
Every body which has been completely b

which has been saturated with the oxygenous principle, returns into the class of incombustibles ; or what is just the same, its tendency to combine with the oxygenous principle is satisfied, and it cannot unite with a new quantity of oxigene, or absorb any more of it. This being admitted, it plainly follows, that, as a number of salts are residues of various combustible bodies, and even an entire class of saline substances are found to have oxigene for one of their principles, and exhibit the characteristics of substances which have been exposed to combustion; these cannot be any longer susceptible of combustion. A numerous train of facts, which shall be hereafter related, concur to justify these assertions : they prove salts to be compound bodies, most of them formed by the union of certain combustible bodies with the oxygenous principle. From this it is easy to understand that incombustibility deserves to be regarded as one of the most certain and invariable characteristics of saline matters. We hope that this will be completely demonstrated of the class of acid salts, when we come to enter particularly into the history of those substances.

Yet there is one class of salts which, though evidently compound bodies, are not known to contain any portion of the oxygenous principle : all the alkalis are of this class. But these are either compounds of incombustible bodies, or if some combustible matter enter into their composition, as we shall have occasion to observe of ammoniac or volatile alkali, it is united with some substance evidently incombustible, which hinders the combustibility of the other matter from being ob-

404.

§ V. Of the general Nature and Composition of Saline Matters.

STAHL, after studying the nature of salts with much attention, was persuaded that they were generally formed of earth and water. He collected all that chemical researches could supply to support and illustrate his theory. But since that illustrious æra of chemical science has been succeeded by one still more illustrious, for both the multiplicity of the researches prosecuted, and the importance of the discoveries which these have produced ; Stahl's theory, which is very perspicuously explained in the works of Macquer, is no longer sufficient to explain the nature and composition of salts. We are no longer content with those remote analogies which forced the most discordant facts into an unnatural union, and bewildered the understanding by exhibiting to it illusive lights. Philosophers now choose rather to confess their ignorance, than to advance ill-founded theories, which may sooner or later be refuted by experiments.

Although the chemical nature of salts be not yet entirely known, and facts allow us not to agree with some of the most eminent philosophers, in acknowledging one saline principle as the base and element of all salts ; yet the component principles of this singular and numerous class of substances, are somewhat better known now than formerly. We know that many minerals contain a very considerable quantity of the principle ; which principle is fixed in matter. This has fully

tion of a number of acids ; and we have the strongest reason from analogy to conclude, that most other salts of that class have the same character. Water, though not one of the immediate principles of salts, is often found united to them, and has a strong affinity with them. As to the matter of fire considered as phlogiston, which some of the most eminent chemists have admitted as a component principle in salts, the nature and existence of that matter are too uncertain to admit of our adopting any determinate opinion in respect to it. The case is not the same with the caloric principle ; it seems evidently to constitute one of their component principles ; in some however, it exists in a much smaller proportion than in the rest, which appear in general to owe to it their fluidity, fusibility, and volatility. The existence of earth in any considerable number of salts has never been experimentally demonstrated. We know only that all the saline bodies which nature exhibits, are mixed with a larger or a smaller quantity of various earthy substances. But these, properly speaking, do not belong to them ; they form no part of their composition, and may be said to be only accessories. The only substances at present acknowledged as general principles of saline matters, are several combustible bodies, the oxygenous principle, a few incombustible matters, and the caloric principle. It is well known that most acids are residues of burnt bodies, and contain oxigene and combustible matter combined together in various proportions. No more has been advanced in treating the nature of salts, is now a mere hypothesis, unsupported

§ VI. *Of the Division and Arrangement of Mineral Saline Matters.*

THE salts belonging to the mineral kingdom are very numerous. A number of them are products of nature, formed by the action of fire, water, and air, and by the dissolution of organic matters. But most of those which are employed in chemistry owe their formation to art, or at least have not hitherto been found among the products of nature. In order to give a methodical view of the history of these substances, we shall divide them in the same manner as stones, into orders, genera, and species. All saline matters may be arranged under two orders.

The first contains those saline substances which have been named *simple*, and which we shall distinguish by the name *primary salts*, because they serve as principles to those of the second order.

The second consists of the secondary, compound, or neutral salts. These are formed by the combination of two or more of the former order, and are of consequence much less simple than they.

Each of these orders shall be divided into several genera, and these again into species.

Nine genera, and eighty-six species of simple and compound salts together, are at present known to exist in the mineral kingdom; and these we shall successively examine*.

* There are three salino-terrene substances, three alkalis, and ten mineral acids. These last, united with aluminous earth, with the three salino-terrene bases, and with the three alkalis, compose 70 compound or neutral salts.—F.

C H A P. II.

Of the three Salino-Terrene Substances.*

ORDER I. SIMPLE or PRIMARY SALTS.

WE give the name of *simple* or *primary salts* to those matters which were formerly known by the name of *simple salts*, and are still so called by some chemists. As it has been shown, by fair experiments, that most of them are really compounds, therefore the title of *simple salts* cannot with any propriety be applied to them, except when they are compared with the salts of the second order. The name of *primary salt*, seems the most suitable for distinguishing them, because they form by combination those neutral or compound salts which we call *secondary*. We shall divide this order into three genera, salino-terrene substances, alkalis, and acids. The examination of the first will occupy this chapter; in the two following we shall give the history of alkalis and acids.

* The title of this chapter is the general denomination of the first genus of the first order of simple or primary saline matters.—F.

Genus I. *Salino-Terrene Substances.*

By this name we denote three substances which have been hitherto regarded as earthy matters, but whose properties plainly show them to be more properly saline *. As these substances possess the distinguishing properties of salts, in conjunction with the characteristics of earthy matters, yet, displaying the latter in a less eminent degree; we therefore rank them before the salts, using them as a link of connection between salts and earths: They differ also from earths as having a stronger tendency than these to combination, as will appear from an examination of their properties.

It is proper to observe, that in our examination of these salino-terrene matters, as well as in our account of the primary salts, we suppose them pure and solitary, though they be never found so in nature; and we avoid mentioning the methods by which they are obtained, from a desire not to break through that elementary order which we have determined to follow through the course of the work. When we come, in the history of neutral salts, to give an account of their decomposition, we shall then have occasion to describe the methods by which chemistry separates those substances, as well as the simple or primary salts, so as to afford them pure.

This first genus contains three species of salino-terrene bodies.

Species

* We have already given some account of them in lithology; but then only as making a part of natural history.—F.

Species I. *Barytes.*

THE first name of this substance was *ponderous earth*, given it by the Swedish chemists Gahn and Scheele, who discovered it in ponderous spar: Bergman and Mr Kirwan have already given it the Latin name *barytes*. Its specific gravity, according to Mr Kirwan, is something more than 4,000. Nature no where affords this earth in a pure but always in a combined state. It was first discovered and distinguished as a peculiar earth by the chemists above-mentioned. Messrs Margraff and Monnet had observed it, but confounded it with absorbent or calcareous earth. Yet the last of these chemists had observed it to possess some peculiar properties, and suspected it to be an earth different in its nature from lime. Its properties, in a pure solitary state have not as yet been very accurately examined; its combinations have been more studied; and what most eminently distinguishes it from other analogous substances, is, its very singular affinities, and the salts which it forms by combination with acids.

Pure barytes, obtained by means which shall be afterwards described, appears under a pulverulent form, very fine and white. I have never found it to affect the tongue with any discernible taste.

It is not yet known whether this substance be liable to alteration from light.

The ordinary fire of our furnaces does not reduce it to fusion: But if heated in a clay crucible, it communicates a blue or greenish colour to the crucible, and assumes itself a slight tinge of the same. This pheno-

menon seems to arise from its power of re-action on clay. M. D'Arcet says that it melts when exposed to a very violent heat in a clay or iron crucible *.

When exposed to the air, it acquires an accession of weight, and combines, though very slowly, with the carbonic acid contained in the atmosphere: the effects of vital air upon it are unknown. We are equally ignorant of the manner in which the oxigenous and the azotic principles, act upon this saline earth. Azote is perhaps one of its constituent principles.

It dissolves in water, but not without difficulty; for 900 parts of that fluid are requisite to dissolve one of barytes. Water thus saturated gives a pale green colour to the tincture of violets †, and still more readily to that of mallows or raddishes. This solution, when exposed to the air, is covered with a thin pellicle; and if it be stripped of this, a new one is produced. This phenomenon is owing to the carbonic acid in the atmosphere: the same thing happens to lime-water, though in a less eminent degree. The solution, when evaporated in close vessels, leaves a residue of barytes; and the weight of the residue affords a proof of the solubility of that substance. It is almost unnecessary to observe, that
in

* This is confirmed by the experiments of M. Lavoisier, who fused barytes in a few seconds, with a flame fed with oxigenous gas. But this barytes appears to have been in some degree impure.—H.

† By tincture of violets, we mean a solution of the colouring part of violet flowers in water. This tincture when newly made is preferable to the syrup of violets, as being much easier affected. But the syrup may be employed in all instances in which the saline matters under examination act with a determinate energy; and we shall therefore often mention it instead of the tincture.—F.

n this, as in all other processes of the same nature, distilled water is to be used.

Barytes acts but very feebly, either in the humid or the dry way, on siliceous and aluminous earth *. Yet it facilitates the fusion of those earths, and assumes a blue or greenish colour when heated with the latter of them. Barytes is less copious in nature than either of the other two salino-terrene substances; but it is probably more copious than it is thought to be. Formerly, it was not known to exist in any body but barytic sulfate or ponderous spar; it was some time since found in England, combined with the carbonic acid, and crystallised like a transparent spar. That salt will be afterwards described. Some modern chemists think it to be a metallic calx or oxide. Its weight, that of the compounds into which it enters, and the precipitate which it affords, when a solution of it with an acid is mixed with an alkaline prussiates, made Bergman long suspect it to be of this nature. We are told, that M. Gahn, a pupil of that celebrated chemist, has actually obtained barytes under a metallic form; but this fact needs confirmation. Its nature therefore is still unknown; because we have never yet been able to separate

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rate

* We must here observe, that in order to give a regular account of the reciprocal action of bodies on each other, no combination of any two bodies is mentioned till after those two have been described. Thus in the history of barytes, I have mentioned only the manner in which it is affected by light, by the caloric, the oxygenous, and the azotic principles, by water, and by siliceous and aluminous earth, because none but these have as yet been described. As we advance in the history of natural substances, we shall learn all the combinations of which it is susceptible. Thus we shall both preserve our order inviolate, and communicate all the necessary information concerning the matters of which we treat.—F.

rate its principles, or imitate its composition. I suspect, as I have already hinted, that the azotic principle, or the base of gas azote, is one of its component parts.

Pure barytes is not applied to any use; solutions of it in water and in acids are used as re-agents, as we shall elsewhere have occasion to observe.

Species II. *Magnesia.*

THAT magnesia which is obtained from Epsom salt, or sulfate of magnesia, and which is likewise found in mother water of nitre, and in a great many stones, &c. is no where in nature to be met with in a state of purity, but always combined with acids. Dr Black is the first chemist who has accurately determined the distinction between it and lime.

This substance, which is obtained by methods to be afterwards described, appears under the form of a very fine white powder, resembling meal both in appearance and to the touch. Its gravity, according to Kirwan, is about 2.33. It has no taste sensible to the tongue; but it affects the stomach as a gentle purgative. It communicates a pale green to the tincture of violets and mallows, and causes turnsol to assume a blue colour. The manner in which light affects magnesia is not well known: it cannot be very powerfully.

According to the experiments of M. D'Arcet, this substance does not melt when exposed to a strong heat. Macquer too observed, that it remained unaltered in the focus of the burning lens of the garden *De l'Infante*. M. Morveau heated magnesia for two hours in the strongest fire that can be procured in Macquer's fur-

nace, with the same effect. M. Butini, a citizen of Geneva, who has published some valuable experiments on magnesia, has observed, that violent ignition contracts and condenses magnesia in such a manner as to render it capable of attacking and corroding an iron surface. We are informed that a small cube formed of a paste of magnesia and water, and exposed to the focus of Parker's lens, was suddenly contracted in all its dimensions. This property seems to indicate a relation between magnesia and aluminous earth; which two substances are often found together in nature, as was observed in the history of steatites, asbestos, and serpentine, &c.

Magnesia, though heated in a retort, loses not the portion of water which it contains: but when subjected to this process, it acquires a very discernible phosphoric quality, as has been observed by M. Tingry, apothecary at Geneva. It suffers no alteration from air, till after being long exposed to it. M. Butini kept ten grains of calcined magnesia in a porcelain saucer covered with paper, in a dry room, for near two years; the only change which it suffered was by gaining one-eighth of a grain of additional weight. It appears that this substance combines slowly with the carbonic acid diffused through the atmosphere.

It dissolves in water but imperfectly and with great difficulty. Four ounces and two drams of pure water, after standing three months in a bottle, with a dram of calcined magnesia, and being boiled together with that substance, afforded M. Butini, by evaporation, a residue which he estimated at one-fourth of a grain.

Mr Kirwan says, that 7900 times its own weight of water is necessary to dissolve it in the ordinary temperature of the atmosphere; that is to say, at about 60° of Fahrenheit's thermometer. Notwithstanding this aversion to solution, magnesia forms a kind of paste with water; that paste indeed is not ductile, but brittle; and the water is readily separated from it by the action of fire, or even of the dry atmosphere. A solution of magnesia has no sensible taste; and it produces but a very trifling alteration on the colour of syrup of violets.

We are not yet well acquainted with the manner in which magnesia acts on pure earths. We know, however, that it does not vitrify with either siliceous or aluminous earth separately; but when heated with both together, it is susceptible of fusion.

Its action on barytes has not yet been examined.

The intimate nature of magnesia is not better known than that of barytes. It has never been shown by experiment to be a modification of some other saline substance, as some chemists have imagined it to be; for magnesia has not yet been either separated into principles by analysis, or imitated by a synthetic process. In the present state of chemistry, therefore, it is to be considered as a simple substance.

Pure magnesia, which Dr Black calls *caustic*, is used in medicine as an absorbent and purgative. For heart-burnings and other complaints occasioned by acidity, it is preferable to common magnesia: because the carbonic acid which this last contains is disengaged in the primary passages by the acids, and produces flatulencies, with all that train of complaints which

pany them : it preserves flesh for a long time, and even restores putrefied bile. Bergman ascribes to it likewise the property of rendering camphor, opium, resins, and gum-resins, soluble in water, and of forming some valuable dyes ; though caustic magnesia be scarce soluble in water. These preparations are unknown in France *.

Species III. *Lime.*

QUICKLIME is a white substance, of more consistency than the two preceding matters : it appears in the form of a grey white stone. Its taste is hot, acrid, and urinous ; it possesses this property in so considerable a degree as to inflame the skin when applied to it. Its specific gravity is about 2.3 ; its form pulverulent and friable ; it is found in places adjacent to volcanoes ; as M. Monnet has observed on the hills of Auvergne.

Lime turns syrup of violets green, giving it a much more intense colour than it acquires from either barytes or magnesia : indeed, it almost destroys the original colour, and in a short time produces in its stead a dirty yellow.

Lime, when exposed to a strong fire, such as that of a glass-house, remains unaltered ; and, in a solitary state, it is not susceptible of fusion. Parker's burning-glass appears to have brought it to the beginning of fusion ; but the lime was placed on a support of charcoal. When heated in a clay crucible, its edges sometimes ap-

X 4

pear

* We learn from Mongez, that lime, soda, and phosphate of urine dissolve magnesia with

pear to melt ; but this phenomenon is occasioned by its acting on the earth of the crucible.

When exposed to the action of the air, lime swells, breaks, and falls into powder ; it then increases greatly in bulk, and is called *lime flaked in the air*. These phenomena are more remarkable, and take place more rapidly when the air is in a humid state. This dry flaking produces heat ; and the dilatation is so considerable as to burst casks, or other wooden vessels in which lime may be contained. After being flaked with air, this substance appears under the form of a very fine white dust ; it has acquired a very considerable increase of weight, and its taste is become much fainter. These phenomena are occasioned chiefly by the water contained in the atmosphere, and the force with which the lime tends to unite with it. And by heating lime which has been flaked with air in a retort, till it becomes red-hot, water is obtained, and the lime returns to its original state.

Water acts very powerfully on quicklime. Pour a small quantity of that fluid on a quantity of lime, the water is instantly absorbed ; and the mass of lime appears as dry as before ; but it soon bursts and breaks into pieces. The heat excited in it by this operation is so strong, as to produce a remarkable hissing noise ; the water is reduced to vapour of a peculiar smell, which communicates a green colour to paper tinged with mallows. The lime soon falls down to a powder ; and the heat, motion, and smoke, gradually disappear. If the process be performed at night, in a place perfectly dark, a great many luminous points are seen over the surface of the lime. All the

pend on the activity with which this salino-terrene substance unites with water. But, in order to produce them, we must employ but a very small portion of the fluid; only so much as the lime can absorb without appearing wet. It appears that the heat disengaged from these two bodies, when they combine with such rapidity, changes their state; and that the lime, when slaked, and reduced to a state of pulverization, contains water in a dry and solid form. This dry state of water—which takes place in many of the combinations in which heat performs a part, and produces solid compounds, whose specific heat is less than that of the bodies of which they are formed,—has not yet sufficiently engaged the attention of chemists; indeed it has been but lately observed. When lime has absorbed as much water as it can contain, without becoming wet, it is then called *dry slaked lime*; water no longer excites any heat in it, and only dissolves it, without producing any very discernible motion. By mixing lime with a proper quantity of water, we obtain milk of lime; and by adding so much water as may be necessary to effect a complete solution of this salino-terrenous matter, we produce a liquor perfectly transparent. Mr Kirwan says, that about 680 times its weight of water is necessary to maintain it in solution at the temperature of 60°.

This solution, which is known by the name of *lime-water*, is clear and limpid. It is but very little heavier than common water, has an acrid urinous taste, communicates a deep green to syrup of violets, and even produces upon it an entire alteration of colour. Lime-water, when evaporated in close vessels, affords very pure water, leaving a residue of quick-lime at the bot-

tom of the vessels: But this residue needs to be very strongly heated, in order to separate entirely the water which still adheres to it. After which this fluid excites heat in it, in the same manner as before its solution.

Lime-water, when exposed to the air, is covered with a dry pellicle, which becomes gradually thicker and more solid. If the first pellicle be taken off, a second is formed, and this process may be repeated till all the water be evaporated. These pellicles have been improperly termed *cream of lime*. This was formerly thought to be a peculiar salt, formed by the union of the finest calcareous earth with water; and much has been written concerning this pretended salt of lime. But it is now well known from the experiments of the celebrated Black, that the cream of lime possesses saline properties less active than those of lime, and that it is a peculiar neutral salt formed by the combination of lime, with a certain acid contained in the atmosphere; and the cream is never formed on lime-water, except when it is exposed to the air. We shall elsewhere examine this salt under the name of *carbonate of lime or chalk*. The manner in which the oxygenous and the azotic principles affect lime is not yet known: it is probable that this base absorbs and fixes some part of gas azote, and at least contains the base of this gas.

Lime combines with siliceous earth in both the humid and the dry way. If sand be mixed with lime newly slaked, or with quick-lime sprinkled with a small quantity of water at the time of mixing, the two bodies become consistent, and form what is called *mortar*. This mixture is liable to many varieties; from the state and quantity of the quick-lime, the quantity of water with
which

which it has been flaked, the circumstance of the sand being mixed with it at the instant of its flaking, or not till some time afterwards; and from the size, the roundness, the inequality, the moisture, or dryness of the sand *. Mortar is also composed with clay baked for bricks, and with puzzolana, which is nothing but clay baked by volcanic fire, and altered by the contact of the air.

Though lime, as well as siliceous earth, be absolutely infusible by itself; yet if these two substances be heated together, the former in a greater proportion than the latter, they are susceptible of fusion, as has been observed by Messrs d'Arcet and Gerhard. Lime likewise melts with a quantity of aluminous earth equal to one-third of its own weight; and Mr Kirwan shows, that it has a greater affinity with this than with siliceous earth. A mixture of all the three substances melts easier and more completely than a mixture of lime with any one of the other two. Thus one part of lime and one of alumine will occasion the fusion of two parts, or even of two and an half of silice. From this fact we understand why so many stones, apparently hard, scintillating, and quartzose, melt notwithstanding, when exposed to a strong fire. The combination, or even the mixture of calcareous earth and clay, with siliceous earth, occasions this phenomenon.

It is not yet known in what manner lime acts on barytes.

One part of calcareous earth produces the fusion of one
half

* See Recherches par M. de la Faye, sur la préparation que les Romains donnoient à la chaux, Paris 1777-8, 1^{re} lie.—F.

half part of magnesia. The glass formed by this mixture, in fire completely dissolves and reduces to fusion a quantity of siliceous earth equal to the quantity of the lime. Accordingly, equal parts of magnesia, lime, and silice, when exposed to fire together, afford a perfect glass.

The intimate nature of lime is unknown. The first chemists who attempted to explain by physical reasonings the phenomena which lime displays in its combinations, and especially when slaked, ascribed them to the fixation of particles of fire in the calcareous stone during its calcination. Such was Lemery's theory. Meyer was of opinion that pure fire was not susceptible of such a combination, and that there was a peculiar acid which combined with it in the lime. This subtle kind of sulphur was the *acidum pingue*, or *causticum* of that chemist. But this doctrine, which has since been repeatedly offered to the world under different names, is overthrown by a series of experiments clearly demonstrating its falsity. Many modern chemists think, that the matter of heat is combined in lime; and that by its disengagement during the slaking of this substance, the light observed by Meyer and M. Pelletier, the ebullition and the evaporation of the water, as well as the peculiar fetid odour exhaled on the occasion, are produced. It appears, however, from what has been said, that the principles and composition of lime are still unknown. Some very distinguished naturalists have thought it to be in all probability a certain preparation of siliceous or aluminous earth effected by the organs of animals; but this is by no means certain. It is surely, however, formed by marine animals; its constituent

stituent parts are certainly united and combined under water during the life of those organic beings ; and azote is certainly *one* of its constituent parts : yet all this is insufficient to determine the opinion of modern naturalists, who require accurate and repeated experiments.

Lime is made use of in many of the arts ; more especially in building. In medicine, lime-water is successfully prescribed in ulcerous cases, &c. It has been thought a powerful lithontriptic. But long experience has shown, that it does not always operate the cures expected from it ; and that where the use of it is too long continued, it produces on the animal fluids an alteration approaching to scurvy or septicity *.

C H A P.

* Mr Kirwan says, that in hot water, lime is $\frac{1}{2}$ more soluble than in water of the common temperature of 60° Fahrenheit. From Lavoisier we learn, that 1000 parts of lime are capable of absorbing and retaining, at the heat of 600° Fahrenheit, 228 parts of water. Bergman makes the specific gravity of lime to be 2,720.—H.

C H A P. III.

Genus II. *Alkali Salts.*

ALKALIS come to be treated of before acids, because they appear to be more simple and less decomposable, and because they resemble in some properties the salino-terrene substances. They have an urinous acrid caustic taste: they turn syrup of violets green, excite heat in uniting with water, absorb both the moisture and the carbonic acid of the atmosphere, and dissolve earths by the force of their tendency to combination *. Three species of alkalis are known; potash, or *vegetable fixed alkali*; soda, or *mineral fixed alkali*; and ammoniac, or *volatile alkali*.

Species I. *Potash.*

THIS species, which we denominate *potash*, has been called *vegetable, fixed alkali*; because, though often met with in minerals, it is found in greatest abundance in vegetables. It has likewise been named *alkali of tartar*, because a considerable quantity of it may be obtained from this saline substance; which will afterwards come under our examination. Dr Black was the first who discovered potash in a state of purity. Formerly this salt was called *caustic fixed alkali*, to distinguish it from common fixed alkali.

This

* To these qualities may be added, the property of rendering oil miscible with water. — H.

This salt, in a state of considerable purity, is white and of a dry solid form : its sapidity is so strong, that it dissolves the texture of the skin. It communicates instantaneously to the syrup of violets a deep green colour, much more observable than that which lime causes the same syrup to assume. It alters, and almost entirely destroys this colour, changing it to a brown yellow.

We know not in what manner light affects this salt.

Potash, when exposed to the action of fire in close vessels, is instantly softened, and by the time when it begins to appear red, becomes entirely liquid. If it be then poured on a smooth hard surface, it cools into a white, opaque, brittle mass. It is not decomposable by heat. A most intense heat, such as that of the furnace of a glass-house, is requisite to volatilize it. In all these operations it dissolves part of the clay vessels in which it is contained.

When exposed to the open atmosphere, it attracts moisture strongly, dissolves into a liquid, and gradually passes into the state of a neutral salt, by absorbing the acid diffused through the atmosphere. By this means, it acquires on such occasions an increase of weight, and becomes capable of effervescing with acids; which never takes place when it is in that state of purity in which we have supposed it. To preserve it pure, therefore, it must be kept in close vessels entirely full of it.

Potash dissolves very readily in water ; it then excites a considerable degree of heat, and exhales a fetid lixivious odour. The solution is colourless ; and when very pure, affords no precipitate. To separate it from

the solvent, the solution must be evaporated to dryness in close vessels. If this operation be performed in open vessels, the acid of the atmosphere is attracted, and renders the pot-ash effervescent. And this absorption takes place so readily ; that if a solution of this salt be exposed to the open air for ever so short a space of time, it suffers an alteration, and is in fact neutralized. In a flask which it does not entirely fill, and which is frequently opened, it is liable to the same alteration. The action of oxigene and azote on this alkali is not known.

Potash combines with silice in the dry way, and causes it to melt together with itself: the two compose a transparent body, known by the name of *glass*. This body is liable to varieties from the various proportions in which the siliceous sand and the fixed alkali are united in it. Two parts of the salt with one of earth afford a soft brittle glass, which attracts moisture, and becomes at length opaque and fluid. This glass is soluble in water, on account of its containing so much more than an equal proportion of alkali. The solution is called *liquor of flints*. It at length deposites part of the earth which it contains, in white semi-transparent flakes, apparently mucilaginous, and so light that they subside but very slowly. Acids seize the alkali, and precipitate the earth, which is called *earth of flints*. But to make this process succeed, care must be taken that the liquor of flints be not too much diluted by the water. In that case, the particles of the earth being too much divided, remain suspended in the liquor, and evaporation is requisite to produce the precipitation. Several chemists are of opinion, that *earth of flint*

not the same with siliceous earth ; on which they think the alkali has produced an entire alteration. They think it to be more like aluminous earth, and believe that by combination with acids, it affords the same salts which are obtained by combining acids with aluminous earth. Such was the opinion of Pott and M. Baumé. But Scheele has shown, that that portion of the earth precipitated from liquor of flints, which is soluble in acids, is part of the aluminous earth of the vessel in which the operation is performed, dissolved by the mixture of alkali and siliceous earth.

The art of making glass is entirely chemical, as glass is nothing but a combination of fixed alkali with siliceous earth. The purity, the proportion, and the complete fusion of these two substances by a fire sufficiently intense, and kept up for a proper length of time, are the three conditions requisite for the preparation of glass, of a proper transparency, of sufficient hardness, and liable to no alteration from the attacks of air. We shall afterwards learn what other substances are mixed with these two in this composition, in order to render the glass more weighty and transparent, and to communicate to it several other properties which render it fitter for the purposes to which it is applied.

Potash acts not with the same force on aluminous as on siliceous earth : but the phenomena which it exhibits, when applied, to alumine, are not yet well known.

This salt appears to be susceptible of combination with barytes, magnesia, and lime. But its combinations with these substances have

rately examined as to admit of our giving a particular account of them here.

Although potash has never yet been decomposed; yet a number of facts with which the reader shall be hereafter made acquainted, concur to show that it is not a simple substance. Stahl, who considered simple salts as a combination of earth and water, thought that fixed alkali differed from the acids only by containing a greater proportion of earth: and in this manner he accounted for its dryness, &c. Potash, in all probability is a combination of some one of the three preceding earths with azote. Some analogies lead me to think that it contains lime. But this conjecture is not yet supported by a sufficient number of facts.

Potash is used in surgery to corrode the skin, and produce inflammation and suppuration in certain cases*.

Species II. Soda.

THIS saline substance, which exhibits the same general characteristics with the foregoing, has received the name of *mineral fixed alkali*: It is found in abundance, combined with a peculiar acid salt in sea-water, and in some spring-waters: sometimes too it is met with in vegetables, but much seldomer than potash. This salt has been called *marine alkali*, from its making a part of marine salt; and *alkali*, or *salt of soda*, because it is oftenest obtained from this substance. We prefer the simple name of *soda*.

The

* Potash is extracted by *lixiviation* and subsequent *concentration*, from the ashes of wood, ferns, and other vegetables. That which we usually meet with in commerce, is manufactured chiefly in North America, or in the northern countries of the continent of Europe. However, this potash is not pure, but always more or less contaminated and neutralized.—H.

The taste of soda is equally strong and caustic with that of potash. It turns the syrup of violets green, and produces the same alteration as potash on this colour: it appears naturally in a dry and solid form. It melts in fire as it begins to become red-hot: a violent heat volatilizes it: it acts on almost all the vessels in which it can be exposed to heat.

When exposed to atmospheric air, it attracts its moisture, and the peculiar acid which it contains: so as to become gradually a neutral salt. The manner in which it is affected by oxigene and vital air is not yet known.

It dissolves in water with heat, and the disengagement of a fetid lixivious odour. It cannot be obtained pure after this solution but by evaporation in close vessels. The lixivate, when exposed to the air, readily absorbs its acid, and becomes neutral. Therefore, to preserve it pure, it must be kept in close vessels.

Soda readily combines with siliceous earth in the dry way, so as to compose glass. Glass-makers have even observed it to be more fusible, and to adhere more readily and firmly with this earth than potash; to which they on this account prefer it. And therefore what was said above concerning the use of potash in glass-making, may be applied to soda. Lastly, this alkali, as well as potash, combines with acids and many other bodies, as we shall afterwards understand.

After this account of the properties of soda, we must observe, that there is no very remarkable difference between potash and soda when both are in a state of purity. It is only in their combinations that the difference of their natures can be distinguished. When combin-

ed with the same acid, they afford neutral salts totally different from each other ; and this is the more surprising because it is impossible to distinguish the one from the other when they are in a pure caustic state, as we have here examined them. Bergman adds another distinctive property of these salts which is well worth knowing ; they have not the same affinity with acids. Potash has a stronger affinity with these saline substances than soda : and is capable to decompose neutral salts, consisting of combinations of the latter. We shall take farther notice of this when we come to examine secondary or neutral salts.

The composition or intimate nature of soda is equally unknown as that of potash. The same analysis leads me to think that soda, as well as potash, is a combination of an earth with azote ; and that it is the difference of the earthy base which forms the characteristic difference between the two salts. Magnesia is possibly the base of soda, as I have for some years hinted in my lectures, and M. Lorgna has since attempted to prove. But the facts on which this opinion is founded, are not sufficiently exact and numerous to justify our considering it as a certain truth. As to its uses, it is employed in making glass, in preparing soap, &c. *.

Species

* The ashes of sea-plants, which are annually burnt to fusion around the coasts of Scotland and its contiguous islets ; and are sold, under the name of *kelp*, are valuable only for the soda which they contain. Soda is likewise produced, separately, by nature, in two lakes in Egypt. It is there known by the name of *natron*—H.

Species III. *Ammoniac.*

WHAT we call *ammoniac* is a salt commonly known by the name of *volatile alkali*. It is distinguished from the two foregoing salts by a keen suffocating smell and a remarkable volatility. This salt, like the fixed alkalis, was not known in a state of purity before the ingenious experiments of Black and Priestley. A certain imperfect neutral salt was mistaken for it, which is solid and crystallised, and possesses indeed some of the properties of volatile alkali, but is really a compound of two saline substances. The property of effervescing with acids, which has been ascribed to volatile alkali, belongs only to that neutral salt, which will be afterwards described.

That which is known in the laboratory under the name of *caustic*, or *fluor volatile alkali*, and in pharmacy by the name of *volatile spirit of sal ammoniac*, is not pure ammoniac; it is only a solution of ammoniac in water. Dr Priestley has shown, that by the operation of a gentle heat, a permanent gas may be extracted from it; and that the water, when deprived of this gas, gradually loses its alkaline properties. This aëri-form fluid is ammoniac, and is known by the name of *ammoniac gas*. This is the body whose properties we must examine, if we wish to know those of genuine *volatile alkali*; as Macquer has very properly observed.

To obtain this elastic fluid, put into a small retort or a glass matrafs a certain quantity of liquid ammoniac. Adapt to the retort, or the matrafs, a curved tube or syphon; the extremity of which is to be immersed

into a pneumato-chemical machine filled with mercury; so that it may be received under an inverted glass filled with the same metallic fluid. Heat the bottom of the retort or matras with burning charcoal or the flame of spirit of wine. Suffer the first part of the elastic fluid, which is mostly common air from the vessel and the tube, to escape; and as soon as the ebullition becomes strong, collect the gas in the inverted glass. The distillation must not be carried so far as to evaporate the water; or at least the tube which is used should in the middle swell into a bowl that may be kept cool, so as to condense the vapour: the ammoniac gas will then be obtained very dry and pure.

The gas thus obtained resembles air, and has the same transparency and elasticity. It is rather lighter, however; its smell is more penetrating; and its taste is acrid and caustic. It instantly converts the blue colour of violets, mallows, and radishes, into a deep green, but does not alter it, as the pure fixed alkalis do. It kills animals, and corrodes the skin, if exposed for any time to its contact.

Though it does not serve to maintain combustion, but extinguishes bodies in inflammation, yet it increases before extinguishing the flame of a wax-candle: it renders its bulk somewhat more considerable, and causes it to assume a pale yellow colour round the edge. This fact proves that ammoniac gas is partly inflammable.

Porous bodies, such as charcoal, sponge, &c. absorb it.

Dr Priestley has discovered, that the electric spark, in passing through ammoniac gas, renders its bulk

three

three times greater than before, and disengages from it a portion of hydrogenous gas. The cause of this phenomenon is hitherto unknown; only it appears that the ammoniac is decomposed in this experiment, and that the two matters, of which, as we shall presently show, it is composed, are separated, and pass into the state of elastic fluids.

Ammoniac gas is one of those elastic fluids which heat dilates the most. Atmospheric air does not combine with this gas; it only dilates and divides it. The action of vital air on this fluid has not yet been examined.

Water readily absorbs ammoniac gas: if in the state of ice, it immediately melts with cold; but on the contrary, this gas communicates heat to fluid water. Water saturated with this gas, or liquid ammoniac, is the substance known by the name of *fluor* and *caustic volatile alkali*. We shall hereafter see that the purest and most concentrated volatile alkali is prepared by receiving the gas into distilled water till the liquid be saturated with it.

Ammoniac gas has no discernible action on earths or salino-terrene substances; but it acts vigorously on acids and a number of neutral salts, as we shall hereafter see. Liquid ammoniac has the same properties as the gas; only, it possesses them in a less eminent degree: For the gaseous aggregation being, according to one of the laws of affinity, much weaker than that of liquids; of consequence, ammoniac gas must have a greater tendency to combination than liquid ammoniac.

This salt has been considered as a combination of fixed alkali with a combustible substance. What gave rise to this conjecture was, that, in many instances, fixed alkalis, when heated with inflammable matters, produce ammoniac. But it was not known whether, on such occasions, fixed alkali entered entire into the composition of ammoniac, or only supplied a peculiar principle, which, by combining with part of the combustible matter, formed this salt. The nature of ammoniac is at present somewhat better known. The fine experiment of Dr Priestley, in which he changed alkaline into inflammable gas, by means of the electric spark, made several chemists suspect this last substance to be one of the principles of ammoniac. M. Berthollet having engaged in a particular series of experiments with a view to determine this, has at length shown ammoniac to be a compound of the hydrogenous and the azotic principles, with a certain quantity of the caloric. He has drawn this induction from observing the action of oxygenated muriatic acid on ammoniac, the decomposition of ammoniacal nitrate in close vessels, and the reduction of metallic oxides by means of ammoniac. Each of these facts will be particularly examined in our history of the compound substances into which ammoniac enters. Here we shall content ourselves with observing, that by heating combinations of the oxides of copper and gold with ammoniac, water and gas azote are obtained, and the metals are reduced. In such operations the ammoniac is decomposed, the hydrogen combining with the oxygen of the oxides, forms the water; the metal

the azote, the other principle of the ammoniac, becoming free, combines with the caloric, and the two are disengaged in gas azote. Berthollet concludes ammoniac to consist of six parts of azote and one of hydrogen, with a certain quantity of caloric *.

Ammoniac diluted in water is administered in a great many diseases. It is aperient, and powerfully incisive. It acts strongly on the skin ; it is prescribed as a remedy for the bite of vipers, and for cutaneous and venereal complaints, &c.

As it is acrid and caustic, it is to be very cautiously used. Externally applied, it is very serviceable in discharging tumours, especially such as are formed by coagulated milk, lymph, &c. I have prescribed it successfully in these cases : it is a ready cure for burnings ; and is often successfully applied for chilblains, &c. It has been long used, and under a variety of names, as a most active stimulant in cases of syncope, apoplexy, &c. But it should be used in very moderate quantities in these latter cases : it is dangerous to administer it internally, unless diluted in a large quantity of water. Alarming excoriations have sometimes been produced on the duct of the œsophagus and the membranes of the stomach, in cases where it has been rashly administered.

C H A P.

**the azote is in proportion to the hydro-*

C H A P. IV.

Genus III. *Acids.*

ACIDS are known by their four taste when diluted in water; they convert blue vegetable colours to red; many of them appear under a gaseous form; they combine rapidly with alkalis; they act much more powerfully than alkalis on combustible bodies, often reducing them to a state of calcination. As inflammable matters, especially metals, are found to contain a considerable quantity of oxigene after they have been exposed to the action of acids; while these again are found to have passed at the same time into a combustible state: from these facts it may be inferred that acids are by no means the simple bodies they were thought to be, but are in general compounds of an inflammable matter, combined with oxigene.

We are acquainted with ten different species of acids in the mineral kingdom. We find also, in the same division of nature, the phosphoric acid, united with iron, lead, and lime.

The carbonic acid.

The muriatic acid.

The fluoric acid.

The nitric acid.

The sulphuric acid.

The boracic acid.

The molybdic acid.

The tungstic acid.

The arsenic acid.

The succinic acid.

We shall here treat of the first six, which are the most plentiful and best known ; the other four will be examined elsewhere.

Species I. *The Carbonic Acid.*

We give the name of the *carbonic acid* to an acid which occurs in great abundance through the whole of nature, and which appearing often in the state of an aëriform fluid, was at first called by the English *fixed air* ; afterwards by Messrs Bewly and de Morveau *the mephitic acid* ; by Macquer *mephitic gas* ; by Bergman *the aërial acid* ; and by Bucquet *the cretaceous acid*. The propriety of the denomination which we have adopted will afterwards appear.

This substance was not always thought to be an acid. Its leading properties were observed by Paracelsus, Van Helmont, Hales, &c. But we are indebted to Messrs Black, Priestly, Bewly, Bergman, and Chaulnes for our knowledge of its acidity.

The gaseous carbonic acid possesses all the apparent characteristic properties of air. Like air, it is invisible and elastic ; and when inclosed in a glass vessel, or floating in the atmosphere, it cannot be certainly distinguished from that fluid. It is one of the principles of atmospheric air, but the most scanty in the composition.

composition *. It is found perfectly pure in subterraneous cavities, which it entirely fills, as in the *grotto del cane*. It is combined with a greater number of natural bodies, such as mineral waters and many neutral salts; spirituous fermentation produces great quantities of it. It is also formed by respiration and the combustion of coals: Lastly, it is constantly exhaled from all parts, and more especially from the leaves, of plants in the shade.

Though this acid, in the state of an elastic fluid, has all the appearance of air, yet it possesses different physical properties; its specific gravity, for instance, is double that of air. Like all other fluids, it may be poured from one vessel into another; it flows from the cock of a wine-cask, after the wine is drawn off; its taste is pungent and subacid; it is instantaneously fatal to animals, because it affords no supply for respiration; it extinguishes flaming tapers, and all bodies in combustion. It communicates to the tincture of turnsole a bright red colour. That colour vanishes gradually in the air as the acid evaporates. It produces no alteration on the colour of violets, as it acts but very feebly on very deep and fixed colours.

This acid has but a very faint tendency to combination; the weakest indeed of all the bodies of the kind.

It

* M. Lavoisier's ingenious experiments have led him to consider atmospheric air as a compound of vital air, carbonic acid, and azotic gas, most commonly in the following proportions.

Vital air,	-	-	-	27
Carbonic acid,	-	-	-	01
Gas Azote,	-	-	-	72
				<hr/>
Total				100

It suffers no discernible alteration from the contact of light.

Heat dilates it, but produces no change in the mixture.

It mixes with vital air, without suffering any alteration; and the mixture will maintain respiration as long as the carbonic acid does not exceed a third part of it. On this account, it admits of being used as a remedy in diseases of the lungs.

It combines with water but very slowly. By shaking these two fluids together, so as to bring them as much as possible into contact with one another, they are made to unite and form an acidulous liquor. Bergman gives to this solution the name of *aërated water*. But this name belongs more properly to water containing atmospheric air, which it may serve to distinguish from boiled water that has been deprived of its air by heat. The colder water is, the more of the carbonic acid does it dissolve. But there is a point of saturation; even the coldest water cannot absorb a quantity greater than is equal to its own bulk.

Water saturated with carbonic acid is somewhat heavier than distilled water. Agitation makes it sparkle; it has a pungent, acidulous taste, and reddens the tincture of turnsol. It is decomposable by heat; which soon brings it to a state of ebullition, and disengages the elastic fluid. The contact of air produces the same effect more rapidly in proportion as its temperature is higher. Therefore, in order to preserve this acidulous liquor, it must be inclosed in vessels properly stopped, and standing in a cool place, or under strong compression.

This acid solution abounds throughout nature. Of it

acidulous and gaseous waters, such as those of Pyrmont, Seltz, &c. consist.

As this acidulated water is a remedy in all putrid disorders, either by drinking or bathing, naturalists have invented an apparatus for impregnating with ease, and with all possible quickness, any quantity of water with as much of the carbonic acid as it can maintain in solution. Dr Priestley, in the year 1772, gave the first account of a process for acidulating water that was offered to the public. Dr Nooth has invented a machine for this purpose, which has been improved by Mr Parker, and still farther improved by Mr Magellan. It is at present to be found in all philosophical laboratories. There is an excellent description, and an engraving of it, in Dr Priestley's *Experiments on the different kinds of Air*, p. 112 to p. 118; and in Mr Magellan's letter in the same work, vol. v. page 83.

The carbonic acid does not act upon siliceous earth. It is well known that acidulated water alone never crystallises siliceous earth; as was some years since represented to the public.

The carbonic acid unites with alumine, barytes, and magnesia. With these substances it forms various neutral salts, which we shall afterwards have occasion to examine.

The combination of this acid with lime dissolved in water, gives rise to an invariable phenomenon, which always indicates the presence of the acid. As soon as it touches the liquid, it produces white clouds, which soon thicken and form a plenteous precipitate. These clouds are owing to the chalk, or carbonate of lime, formed by the combination of lime with the carbonic acid. This

new salt, not being soluble in pure water, is separated, and subsides to the bottom of the fluid. Lime-water is therefore a test, by which we may distinguish the nature and the quantity of the acid under examination. If, after this precipitation, more of the acid be added, the precipitate will again be dissolved by the additional quantity of the carbonic acid, and will then disappear. Here is a second characteristic by which this acid may be known. The chalk thus dissolved by the addition of a second quantity of the carbonic acid, is again precipitated when the liquor is heated or exposed to the air, or lastly, by all the processes which carry off the superfluous quantity of the carbonic acid. Thus, I have remarked, that the caustic fixed alkalis and pure ammoniac, when poured into a solution of chalk with the carbonic acid, cause a precipitation by absorbing part of the acid.

Acidulated water, if poured into lime-water, produces upon it precisely the same effects.

The carbonic acid combines rapidly with the three alkalis. If a small quantity of pure caustic fixed alkali, in a liquid state, be put into a vessel filled with this acid, obtained from chalk or from beer in a state of fermentation; and the mouth of the vessel be immediately closed with a wet bladder: the bladder will be seen to contract gradually, on account of the vacuum produced in the vessel by the alkali absorbing the carbonic acid. The combination of these two acids is attended with heat; and the sides of the vessel are soon covered with crystals which become gradually larger. This salt is called *carbonate of potash*, or *carbonate of soda*, according as the one or the other of these fixed

alkalis is employed. These two genuine neutral salts were formerly called *salt of tartar*, and *salt of soda*. We shall examine their properties in the following chapter.

Ammoniac gas, and the aëriform carbonic acid brought into contact in a close vessel, also produce instantaneously a vacuum, heat, and a thick white cloud which forms into regular crystals, or simply into a crust, on the sides of the vessels. This is an imperfect neutral salt, to which we may give the name of *ammoniacal carbonate*, and which was formerly called *concrete volatile alkali*, *English salt*, &c.

The carbonic acid does not adhere to all of these bases with the same force. According to Bergman, barytes is the substance with which it has the greatest affinity; next in order come lime, potash, soda, magnesia, and ammoniac. We will have occasion in the history of neutral salts to take notice of the facts on which Bergman has established this order of affinities.

The nature and composition of this gaseous acid, have for some years much engaged the industry of chemists. Priestley, Cavendish, Bergman, and Scheele, seem to agree in thinking it a compound of vital air with phlogiston. But as the existence of that principle has been with reason questioned by a number of celebrated French chemists, who have urged many difficulties and objections against it, to which no satisfactory answer can be given, we cannot therefore admit of this theory. I once thought that the carbonic acid might be a compound of inflammable gas with pure air; but the discovery of the nature and the decomposition of water renders that conjecture improbable; and M. Lavoisier
has

has supplied it in its room a fact supported by demonstrative evidence.

This chemist, to whom the science is indebted for so many ingenious and nice experiments, burnt a certain quantity of charcoal, deprived of all its hydrogenous gas by a previous calcination in close vessels,—in inverted glasses, filled with mercury above a portion of air: for he had observed, that if the operation were performed without the precaution of calcining the coal, drops of water would be obtained, and would necessarily render the calculation inaccurate. This operation was performed by means of a quarter of a grain of agaric tinder, placed on a bit of coal, and covered with a very small quantity of phosphorus: a piece of iron wire bent, and made red hot, passed through the mercury, so as to kindle the phosphorus; the phosphorus communicated the inflammation to the agaric tinder, which again communicated it to the coal; the inflammation was very rapid, and accompanied with much light. The whole apparatus being cold, M. Lavoisier introduced into the glass a portion of liquid fixed caustic alkali; which absorbing the acid formed during the combustion, left part of the vital air as pure as at the beginning of the experiment. This chemist is of opinion, that in this experiment the oxigene, which by combining with caloric formed the vital air,—produced a portion of the carbonic acid by combining with the matter of the coal, while the other principle of the same vital air was disengaged under the form of heat and light. A portion of ashes remained; and the quantity of the acid formed was equal in weight to the vital air consumed, and the weight which the coal had lost. From a number of ex-

periments of this kind, M. Lavoisier concluded, that a quintal of the carbonic acid, the name of which the reader may now perceive to be founded on its nature, consists of about 28 parts of pure carbonaceous matter, and 72 of oxigene.

He thinks, that in the respiration of animals, a real carbonaceous matter is actually disengaged from the blood, which by combining with the oxigene of the atmosphere, forms the carbonic acid, which is constantly produced by respiration; and that in the same manner the carbonic acid, disengaged in spirituous fermentation, is produced by the combination of the carbonaceous matter of sugar with the oxigenous part of water.

Several philosophers have observed, that this acid, in a state of fluid elasticity, possesses the property of preserving animal substances, retarding their putrefaction, and even restoring them to a sound and fresh state after putrefaction has begun to take place. From this fact Macbride has inferred, that the acid unites with the body, thus restoring to it what it lost by putrefaction. This latter phenomenon, in his opinion is occasioned by the natural decomposition of organic matter, and the dissipation of the carbonic acid they contain, which he calls *fixed air*; and therefore he asserts the use of this acid to be indispensably necessary, in order to afford to animals a supply of what they are so constantly losing, and to restore the fluids when altered by motion and heat. He acknowledges the existence of this acid in fresh vegetables, more especially in such as are susceptible of fermentation; as a decoction of barley which has been suffered to germinate, the infusion of raisins, &c. all of which, he thinks, may be with equal
property

propriety prescribed in diseases occasioned by the septic motion of the humours ; such as the scurvy.

Water impregnated with the carbonic acid has been also proposed as a remedy in putrid bilious fevers ; and has been used with success in a number of instances : The English are said to use the carbonic acid, mixed in a low and unequal proportion with common air, in diseases of the lungs.

It has been strongly recommended as a lithontriptic, or solvent of the stone in the bladder. But there is no well authenticated instance of its being successfully used in France again this dreadful distemper. Besides, this is contradictory to what Scheele and Bergman have discovered concerning the stone in the bladder ; of which we shall elsewhere speak.

The newspapers have given accounts of a number of cancerous cases cured in England by the use of carbonic acid. But we can assert, that we have often seen it used in such cases, and have even tried it ourselves, still without effect. After the first applications, the cancerous ulcer seems to assume a more favourable aspect ; the sanies which usually flows from it becomes white, consistent, and somewhat pure ; the flesh assumes a fresh lively colour ; but these flattering appearances are fallacious, and do not continue ; the ulcer soon returns to its former state, and its progress goes on as before.

The period of the first discovery of this acid by Dr Black is to be considered as one of the most illustrious æras of chemical science. To point out the influence of this discovery upon the science, we shall here offer the following remarks. 1. It has made us acquainted with a peculiar acid. 2. It has explained the cause of

the effervescence of the common alkalis, chalk, calcareous spar, and magnesia, when mixed with acids stronger than themselves. 3. It has enabled us to distinguish all alkaline matters as existing in two states, *pure and caustic*, or *soft*, with the property of causing effervescence. 4. It has thrown new light on the history of the elective attractions of ammoniac and chalk for the acids. 5. It has furnished us with one of the first instances of an acid preferring lime to the fixed alkalis. 6. The history of places containing mephitic air, caverns which are instantly fatal to the life of animals, is become since this discovery more simple and intelligible. 7. To the former analyses of waters, we have been enabled to add by this discovery an accurate knowledge of gaseous, spirituous, and acidulous waters; so that we can now produce by rule the most perfect imitations of them. 8. It has likewise made us much better acquainted with the solutions of iron contained in various waters; and has taught us how to make up martial waters exactly resembling those of nature. 9. It has made us acquainted with a new class of neutral salts alkaline and metallic, which have the carbonic acid for one of their principles, and to which we shall therefore give the name of *carbonates* in this work. 10. It has opened a new tract for the researches of naturalists and chemists, and has roused that ardour for such pursuits, to which we are indebted for all the fine discoveries which have been made since that period. The name of Black will therefore be famous in the annals of chemistry as long as the science shall be cultivated.

As to the production of this acid by the electric spark passing through vital air, we must observe, it

in the experiments of M. Landriani, the iron used as the conductor of the electric fluid, is evidently the cause of the phenomenon by means of the plumbago, or carbure of iron, which it contains. The trivial quantity of the acid obtained, is an unequivocal proof of this.

There are, no doubt, many cases in which the carbonic acid is decomposed and resolved into its principles, as well as other acids: Thus, for instance, water saturated with this acid is much fitter than distilled or common water for the production of vital air on leaves exposed to the rays of the sun: the vegetable substance seems to absorb the carbonaceous matter, while the light, acting like heat, contributes by separating the oxigene, to the production of vital air. It is likewise very remarkable, that certain oxides of iron, distilled in a pneumato-chemical machine, afford only carbonic acid as they pass to the state of æthiops or black oxide of iron. This depends either on the carbonaceous matter, or the plumbago contained in several kinds of iron. The carbonaceous matter, by absorbing part of the oxigene of the iron, forms the acid which is disengaged. These newly discovered facts will be explained more at length in some of the following chapters of this work *.

Species II. *The Muriatic Acid.*

In the laboratories, the name of *marine acid*, or *spirit of salt*, or *liquid muriatic acid*, is given to a fluid of the consistency of water, of a taste strong enough to

Z 3

corrode

* According to Kirwan, the proportion of carbonic acid to that of common air, is, as 100 to 48,81. The proportion of muriatic acid, is as 12,6384 to 69,50 to 1000000.

corrode our organs when it is concentrated ; but which, when diluted in water, affects the tongue only with a sourness and stipticity. This fluid, when perfectly pure, is absolutely colourless. When it is red, or citror-coloured, like the marine salt of the shops, it owes its colour to some combustible substances, frequently to iron, which alters it. This acid is obtained from marine salt or muriate of soda, as we shall see in the history of that salt. If strong and concentrated, it exhales when exposed to the air a white vapour or smoke. It has a lively penetrating smell, which when faint or much diluted, resembles the smell of citrons, or the apple called the *golden rennet*. It is then called the *fuming muriatic acid*. Its vapour rises most copiously when the air is moist. If, on opening a flask full of this acid, you put your hand to its orifice, you feel a sensible heat ; which is occasioned by the combination of the acid in the state of vapour with the water of the atmosphere.

The muriatic acid communicates a deep red to the syrup of violets, and all blue vegetable colours, but does not absolutely destroy them. This liquor, however concentrated and fuming, is not muriatic acid in a pure and separate state ; but muriatic acid combined with a considerable quantity of water. Dr Priestley has established this truth beyond a doubt, by showing that this acid may be reduced to a gas, and rendered permanent in that state, over a portion of mercury, by the temperature and pressure of the atmosphere : we must therefore examine the properties of this gas, if we wish to acquire a knowledge of those of the muriatic acid, unmixed and in a state of purity.

The muriatic acid gas is obtained by heating the liquid fuming acid in a retort, the extremity of which enters a bell-glass full of mercury. The gas being much more volatile than the water, passes through the retort into the glass ; it displays all the apparent properties of common air, but is more ponderous. It has a keen penetrating odour ; and is so caustic that it inflames the skin, and often occasions violent itchings. It suffocates animals, and extinguishes the flame of a taper, after magnifying it and causing it to assume a green or bluish flame round its edges. Spongy bodies absorb this acid.

Light does not appear to alter it in any sensible degree. Heat rarefies it, and increases its elasticity amazingly. Atmospheric air, mixed under bell-glasses with muriatic gas, causes it to assume a fummy or vaporous form, and is gently heated ; from which it appears that a combination actually takes place. When the air is humid, these vapours are more discernible : M. d'Arcet has observed that they are not perceptible on the tops of high hills, where the air is very dry. The white vapours exhaled by the muriatic acid gas are therefore owing to the water contained in the atmosphere. Neither the liquid acid nor the gas absorbs vital air in a state of elasticity, in any sensible degree ; yet some properties, which we shall mention by and by, enable them to combine with the oxygenous principle. It is asserted that the liquid muriatic acid may be caused to absorb a portion of vital air, by shaking them violently together.

The muriatic acid gas combines rapidly with water. Ice, on coming into contact with it, instantly melts, to

absorb it. Water uniting with this gas acquires a considerable heat. When saturated with it, it cools and becomes the same with the liquid acid from which the gas was obtained ; it exhales white vapours, is colourless, reddens syrup of violets, &c. We shall afterwards see, that the most concentrated and pure liquid muriatic acid is obtained by saturating pure water with the elastic fluid.

The muriatic acid gas has no power of action on siliceous earth ; it combines with aluminous earth, and by this combination forms aluminous muriate.

It unites with the salino-terrene substances, forming in combination with them barytic, magnesian, and calcareous muriates.

Its combination with potash is *the febrifuge salt of Sylvius*, or muriate of potash : with mineral alkali or soda, it gives marine salt, common salt, or muriate of soda.

The muriatic acid gas when brought into contact with ammoniac gas, acquires a considerable heat. The two elastic fluids penetrate each other, a white cloud instantly rises, the mercury is elevated in the glasses, and the sides of the glasses are soon covered over with ramified crystals, which are sal ammoniac, or ammoniacal muriate. If the two gases be very pure, they disappear entirely when the concretions are formed, and the heat disengaged. This experiment among others proves, 1. That bodies which pass from a liquid to a solid state, absorb in their transition a certain quantity of the caloric principle, or the matter of heat ; for the cause which converts the muriatic acid into a gas,
is

is its receiving an additional quantity of heat. 2. That the heat absorbed by elastic fluids, in their *aërifaction*, is disengaged when they return to a liquid or solid state. 3. That the elasticity of fluids is produced by their absorbing and combining with heat; and that all aëriform fluids are compound bodies, which owe their form to fixed heat, or the caloric principle, as we have elsewhere shown.

The muriatic acid absorbs the carbonic acid; but the reciprocal action of these two acids has not yet been properly examined. The muriatic is known to be the stronger of the two; for it disengages the carbonic from all its bases, and enters itself into combination with them. Bergman arranges its attractions for the different alkaline bases in the following order, proceeding from that with which it has the strongest to that with which it has the weakest affinity: barytes, potash, soda, lime, magnesia, ammoniac, aluminés.

The intimate nature of the muriatic acid, and the principles of its composition, are unknown. Beccher imagined it to consist of sulphuric acid with *mercurial* earth; because he had ~~observed~~ that acid to have a strong affinity, and combine very readily, with all the bodies in which he admitted the existence of this principle, such as arsenic, mercury, &c. Stahl has not illustrated Beccher's opinion concerning this acid. And among all the ingenious experiments of the moderns, there is none which throws any light on the constituent principles of the muriatic acid. As its base is unknown to us, we cannot determine whether it admits of two states of saturation with oxigene; in one of which, the base being completely saturated, the acid must be

stronger, while in the other the base being combined with a smaller quantity of oxigene, the acid must be weaker, according to what has been observed of the nitric, the nitrous, the sulphuric, and the sulphureous acids. Even the existence of oxigene in the muriatic acid has not yet been fully evinced; it is only from analogy that it has been admitted.

Scheele is the only chemist who has done any thing of consequence on this head. In the year 1774, he made an important discovery concerning the different states in which this acid exists. By distilling a quantity of muriatic acid upon oxide of manganese, he obtained this acid in the form of a yellowish gas, of a very pungent smell, amazingly expansive, and capable of dissolving any metal with facility, mercury or gold not excepted. He thought that, in this instance, the manganese, which he imagined to be very greedy of phlogiston, absorbed the phlogiston of the muriatic acid; and he therefore called this acid, after it had undergone this operation, *dephlogisticated marine acid*; and thought that it dissolved gold, from its avidity to unite with a new portion of phlogiston. No unequivocal experiment, however, demonstrated the existence of the inflammable principle in this acid: and in the year 1780, I suspected that it was the base of vital air contained in the manganese, which entered into union with the muriatic acid; as may be seen in the first edition of my Elements under the articles *Aqua Regia* and *Manganese*, &c. M. Berthollet, my fellow-academician, has shown that conjecture to be a certain truth, by a series of accurate and ingenious experiments.

A distillation of the muriatic acid on oxide of manganese, afforded him yellow vapours without the help of fire. If the retort be heated, and the vapours received in flasks full of water, and immersed in ice, a very small portion of the acid is dissolved, but the water is soon saturated; after the saturation of the water, the rest of the gas assumes a concrete form, and falls in crystals to the bottom of the liquor. This salt melts, and rises in bubbles with the most moderate heat.

The oxygenated muriatic acid in a liquid form, or dissolved in water, has, according to M. Berthollet, an harsh though not an acid taste; it whitens and destroys vegetable colours, without changing them first into a red; it neither expels the carbonic acid from its bases, nor produces any effervescence with alkaline substances saturated with that acid; in short, it possesses not the usual properties of acids. If heated with quicklime, it effervesces, and gives out vital air, so that the remains is nothing but calcareous muriate; which is evidently produced by the disengagement of the oxigene with which the acid was saturated. The oxygenated muriatic acid produces likewise an effervescence when it combines with pure ammoniac. The result of this combination is, on the one hand, water; on the other, azotic gas. In this instance, the oxygenated muriatic acid and ammoniac are both decomposed; the hydrogen, which is one of the principles of the ammoniac, unites with the oxigene, with which the muriatic acid is super-saturated, and by their union the water is formed; while again, the azote, the other principle of the ammoniac, uniting with the caloric, escapes under an elastic form, and produces the effervescent motion
observed

observed in this experiment. Lastly, the oxygenated muriatic acid converts metals into oxides, and dissolves them without occasioning effervescence. It destroys vegetable colours, as it passes into the state of common muriatic acid. All these experiments prove, that Scheele's dephlogisticated muriatic acid, is a combination of this acid in a pure state, with the base of vital air, or the oxygenous principle; and that its proper name is, *aërated or oxygenated muriatic acid*, as I have shown in my first edition. M. Berthollet has not yet determined what quantity of oxigene the muriatic acid must absorb, in order to acquire the properties of oxygenated muriatic acid*. In March 1787, he discovered that oxygenated muriatic gas, received into a lixivate of caustic potash, forms a crystallisable neutral salt, which, like nitre, or even in a greater degree, produces detonation on burning coals; affording by the action of the fire very pure vital air, or oxygenous gas, and leaving a residue of muriate of potash. These experiments concur to support the theory which I offered to the public seven years since, concerning the nature of the oxygenated muriatic acid; for the detonation of oxygenated muriate of potash is plainly owing to its containing an extraordinary quantity of oxigene. Soda forms only a deliquescent salt with the oxygenated muriatic acid.

The muriatic acid is made use of in several of the arts, and more especially in the art of assaying in the humid way†. In medicine, it is well diluted in water,

* See *Journ. de Physique*, tome xxvi. page 321, Mai 1785.

† See Bergman, de *Docimasia humida*, Opusc. Vol. II. Or the English translation of his *Opuscula*.—H.

ter, and administered as a diuretic, an antiseptic, and a cooler; it is the chief ingredient of the Prior de Chabriers cure for ruptures. It is externally applied as an escharotic, to destroy altered flesh, as a cure for the gangrene in the throat, aphthæ, &c. Mixed with a certain quantity of water, it composes a bath for the feet, used by some people, and considered as a secret, for drawing the gout from the more vital to the inferior parts.

But the oxygenated muriatic acid has been known for too short a space of time to admit of its being much used in the arts. M. Berthollet thinks that it may be successfully employed for discovering in a few minutes or hours, what effects the action of air would produce on coloured stuffs, and thus determining the fixity or alterability of the colours: he has of late recommended it for whitening linen and unbleached yarn: and the first trials, which have been made in Paris on a pretty extensive scale, promise favourably. It may likewise be advantageously employed for whitening in a short time the yellow, and more especially the green wax from our islands *.

Species III. *The Fluoric Acid.*

THE fluoric acid, discovered by Scheele, has received this name because it is obtained from a sort of earthy neutral salt, with which we shall afterwards get acquainted under the name of *fluor spar*.

This acid when pure has a gaseous form, and we must

* The oxygenated muriatic acid is now generally used in bleaching, in consequence of the experiments of M. Berthollet. By M. Chaptal it is recommended to make old books and manuscripts legible. In its concrete form, it is crystallised into quadrangular prisms, truncated very obliquely, and terminated by a lozenge.—H.

must examine its properties as it exists in that state. The fluoric acid is more ponderous than common air. It extinguishes lights and kill animals. It has a pungent penetrating smell, nearly the same with that of the muriatic acid gas, but rather less keen. Its causticity is such that it corrodes the skin, however short the space of time during which it is exposed to its contact. It suffers no sensible alteration from light. Heat dilates it, but without changing its nature.

The water contained in atmospheric air, enables it to destroy the transparency of the fluoric acid, and convert it into a white vapour; which it does more or less readily, according as it contains a greater or a less quantity of water. This phenomenon resembles that which the muriatic acid presents on the same occasion; but the vapour of the fluoric gas is thicker than that of the other.

The fluoric acid gas unites eagerly with water, and heat is produced at the instant of their union. A peculiar phenomenon appears on this occasion, namely, the precipitation of a very fine white earth, which appears to be siliceous earth. From this circumstance it appears that the acid is far from being pure in the state of elastic fluidity. It becomes pure, therefore, only when the earth, which adhered to it when it was volatilized, has been separated by the action of water. A solution of this gas in water constitutes the acid spirit of fluor; the smell and causticity of which are very strong, when the water is saturated with it. This liquid acid communicates a strong red colour to the syrup of violets. According to Scheele and Bergman, it possesses the singular property of dissolving siliceous earth. Although the fluoric acid gas, on uniting with water,

ter, deposite a considerable quantity of this earth, yet it still retains so much that alkalis cause it to afford a new precipitate.

Dr Priestley observed, that the fluoric acid gas corroded and penetrated common glass, and found it necessary to use thick glass bottles for his experiments. Macquer thought that the acid produced this effect only when in a gaseous state, but was incapable of attacking glass when liquid or diluted in water. This opinion is founded on the circumstance of water's precipitating the siliceous earth, which is maintained in a state of solution in the fluoric gas. But it is to be remembered, that the water does not entirely separate the earth from the acid; and therefore the fluoric acid must retain, even in a fluid state, the power of acting on glass and siliceous stones.

The liquid fluoric acid may be decomposed like spirit of salt by heating it in a retort, the extremity of which enters a bell-glass full of mercury. By this means the acid is obtained in gas, and leaves the water pure.

The two French chemists who, in the year 1773, published, under the name of M. Boullanger, a series of experiments on the vitreous spar, or the sparry fluor, are of opinion that the acid of this spar is nothing but a combination of muriatic acid with an earthy matter, which water only is capable of separating from it. But Scheele has successfully combated this opinion. He considers it as a peculiar acid, strikingly distinguished from all others by the various combinations of which it is susceptible. And his opinion is at present very generally received among chemists.

The fluoric is the only mineral acid capable of dis-

solving siliceous earth. Bergman and Scheele were of opinion, in the year 1779, that this earth might very probably be a compound of the fluoric acid with water; because the fluoric acid gas deposits no small quantity of siliceous earth, when brought into contact with water. But an experiment of M. Meyer's has since proved, that the earth precipitated on that occasion comes from the glass vessel, part of which is dissolved by the acid. That chemist took three cylindrical tin vessels, into each of which he put an ounce of *vitreous spar* and three ounces of sulphuric acid, which having a greater affinity than the fluoric acid with lime, is successfully employed to separate this latter acid: to one of these mixtures he added an ounce of pulverized quartz; to the second an ounce of powder of glass; the third he left pure without any addition: in each of the cylinders he hung a wet sponge, and closing up the vessels, exposed them to a moderate temperature. Half an hour after, he found a siliceous dust deposited on the sponge of the mixture containing the glass; at the end of twelve hours, the sponge of the vessel containing the quartz was likewise covered over with an earthy incrustation; but even after several days the sponge of the third vessel exhibited no such appearance. Bergman sent an account of this experiment to M. de Morveau, letting him know at the same time, that he now gave up his opinion concerning the formation of siliceous earth by the combination of the fluoric acid gas with water. The precipitation is therefore owing to the glass dissolved by the fluoric acid gas; and the acid is not pure till after the precipitate has been separated from it by water and alkalis.

The fluoric acid, either in a gaseous or a liquid state, unites with aluminous earth, forming with it *aluminous fluat**, a sweet tasted neutral salt, which readily assumes the consistency of a thick jelly.

It combines also with barytes: the salt resulting from this combination, to which we give the name of *barytic fluat*, is a pulverulent substance.

With magnesia the fluoric acid forms a crystallisable salt, *magnesian fluat*.

It forms a precipitate with lime water, producing instantly *calcareous fluat*.

It combines with potash to form *fluat of potash*; with soda, it produces *fluat of soda*; lastly, combining with ammoniac, it forms the salt which we call *ammoniacal fluat*.

This short account of these saline combinations shows the fluoric acid to be evidently different from the muriatic. Its affinities with the different bases afford new proofs in support of the same truth. Bergman observes, that the fluoric acid, when united with potash, may be separated from it by lime-water, which causes the solution of that salt to afford a precipitate. The same thing takes place on a solution of the barytic fluat, which becomes muddy when lime is put into it. Bergman gives its elective attractions in the following order; lime, barytes, magnesia, potash, soda, ammoniac: but he confesses that more experiments are necessary to establish fully this order of affinities.

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* According to the methodical nomenclature which we have proposed, the word *fluorate* is here to be used; but we contract it into *fluat*: and we shall do the same for the sulphuric acid, using *sulphat* instead of *sulphurate*.—F.

The fluoric acid gas has not as yet been applied to any purpose in the arts : but its power of dissolving siliceous earth, will in all probability render it very useful in chemical operations, when processes for obtaining it more conveniently than at present, shall have been introduced.

Species IV. *The Nitric Acid.*

WHAT is called *spirit of nitre* in the laboratory, is a combination of this acid with water. In a liquid state and pure, the acid is white ; but if altered in the smallest degree, it becomes yellow or red ; and there arises from it in great abundance a vapour of the same colour. It is so caustic that it burns and destroys instantaneously the organization of the muscles. It reddens syrup of violets, and entirely destroys its colour.

On being exposed to the rays of the sun, it acquires according to Scheele, an higher colour and greater volatility ; and from this it appears that light acts upon it: As it acquires a deeper colour, vital air is disengaged from it.

Heat volatilizes this acid, and separates the colouring matter in the form of red vapours.

When red, it unites eagerly with water, which assumes in consequence, a green or blue colour : it appears to have acquired a considerable degree of heat in entering into this combination. When united with a large quantity of the fluid, it forms *aqua fortis*.

The white and the red nitrous acids were formerly considered as being of the same substance, only concentrated

ted in different degrees; the higher coloured was
ought to be the most concentrated of the two. But

are now better acquainted with the nature of this
ne substance, and know it to be capable of existing
two different states. In one of these the acid of nitre
destitute of colour, more ponderous, and less vola-
ile, and emits only a white smoke; in the other, it is
a colour varying in shade from a yellow to a brown
l, is more light and volatile, and is constantly emit-
ing red vapours, in greater or less abundance, accord-
ing to the temperature to which it is exposed. Berg-
man distinguishes between these two states of the acid
of nitre, by giving to the one the name of *dephlogisti-*
cated, to the other that of *phlogisticated*; we give to
the former, the white, the name of the *nitric acid*; to
the coloured, the name of the *nitrous acid*. The cause
of these distinctions will hereafter be shown: Only, we
may here observe, that if the coloured and fuming ni-
trous acid be distilled in a glass retort, the red part
is first off in vapour, and what remains is a white
and colourless acid. The darker the colour of the spi-
rit of nitre subjected to distillation, so much the greater
the quantity of the vapours obtained, and so much
less the portion of the white acid remaining in the re-
tort; and *vice versa*, when the nitrous acid heated in
the retort is of a bright red colour, very little vapour,
but a great deal of the white acid is obtained. This
fact shows the red acid to be more volatile than
the white. And as all coloured spirit of nitre is com-
posed of the two, they are to be separated by a pro-
cess of distillation judiciously conducted. In this ope-
ration a certain quantity of vital air is always disenga-

ged, which may be collected by applying a pneumatoc-chemical machine to a balloon. We must remark, that when the vessels are red-hot, certain red vapours are constantly separated even from the whitest nitric acid; and the colour of the acid is also changed, so that it becomes of a flame-red: But the change produced by heat immediately disappears when the acid returns to its former temperature, and the vapour also returns to a liquid. The same thing happens when a portion of the nitrous acid, highly coloured, is united with water; a red vapour is disengaged and passes into the atmosphere; the heat which then takes place, increases the colour of the acid which had been weakened by the water; what remains after the evaporation is not nitrous, but nitric acid; and the change is instantaneous. When heat, by the assistance of light, produces this change on the nitric acid, a quantity of vital air or oxygenous gas is disengaged, proportioned to that of the nitrous gas which is formed on the occasion. This decomposition of the nitric acid, and the change of it into the nitrous, takes place in consequence of the mutual affinities between light, caloric, and oxigene. In this instance the glowing heat of our vessels acts like that of the rays of the sun.

The nitric acid acts not upon siliceous earth: it combines with aluminas, with barytes, with magnesia, with lime, the three alkalis: with these substances it forms the aluminous, barytic, magnesian, and calcareous nitrates, nitrate of potash, nitrate of soda, and ammoniacal nitrate. All these salts shall be hereafter particularly examined. The salts formed by the union of the same bases with the nitrous acid are somewhat different from

these,

else, and are distinguished in our methodical nomenclature by the name of *nitrites*.

The nitric unites with the carbonic acid, absorbing eagerly. The mutual action of these two bodies is at yet well known.

The nitric enters very rapidly into combination with the muriatic acid. The alchemists gave the name of *aqua regia* to this compound, because they used it to dissolve gold, the king of metals : we shall henceforth call it the *nitro-muriatic acid*. It must have always appeared singular, that two acids, neither of which is by itself capable of acting upon gold, should by combination acquire the power of dissolving it. The alchemists, content with having found a solvent for that precious metal, gave themselves no concern about the cause of the phenomenon. It is but a few years since two Swedish chemists, Scheele and Bergman, first sought to discover what alterations the nitric and the muriatic acids produced on each other by mutual combination. Scheele observed, what we have already taken notice of, that by distilling a portion of muriatic acid on calx or oxide of manganese, the acid was caused to diffuse a yellowish vapour of the same smell with *aqua regia*, which destroyed blue vegetable colours, and acted with a powerful force upon metals,—more especially upon gold, which it dissolved as well as the nitro-muriatic acid. He thought that it acquired these properties in consequence of being deprived of its phlogiston by the oxide of manganese, and that what caused it to act so forcibly on combustible bodies was its eagerness to regain the principle which it had

lost. For this reason he gave it the name of *de-phlogisticated marine acid*. Our first observation here is, that, this explanation of these phenomena is directly contradictory to the theory of Stahl, which Scheele in general appears to have adopted and extended : for the muriatic acid is said to acquire, by the loss of its phlogiston, a set of properties which Stahl attributed to the presence of that principle ; namely volatility, a strong smell, and a power of acting on inflammable matters. Besides, we are of opinion, that all these phenomena may be much more satisfactorily explained by the new theory : and this we shall very soon show.

Bergman thinks that the nitric acid seizing on the phlogiston of the muriatic acid, is partly dissipated into vapour, and that what remains of the muriatic acid is then precisely in the same state with the vapour which arises from the distillation of this acid on oxide of manganese. Thus, what enables the nitro-muriatic acid to dissolve gold, is its containing a portion of *de-phlogisticated marine acid* : and this mixed acid is often nothing but marine acid. Such is the opinion of the celebrated chemist of Upsal. The following appears to me a better account of the facts. When a quantity of nitric acid is poured upon a quantity of muriatic acid, heat is excited between the two liquors, and they assume a colour ; an effervescence takes place, and a kind of mixed smell arises, not so pungent as that of the muriatic acid, but quite peculiar, and resembling that which this acid affords when distilled on oxide of manganese. Mr Berthollet has discovered, that a portion of oxygenated muriatic acid is disengaged during this rapid re-action of the two acids.

On this occasion, therefore, the muriatic acid deprives the nitric of part of its oxigene, and is dissipated in the form of oxygenated muriatic gas; yet a portion of it still remains saturated with oxigene and nitrous gas; and this mixture is *aqua regia*. From this we understand why so small a proportion of the nitric acid is necessary to communicate to the muriatic the properties of *aqua regia*; and why both the nitro-muriate of gold, and the nitro-muriatic acid, afford when distilled nothing but muriatic acid. But we must observe, that, as much more nitric acid than is necessary, is generally used to super-saturate the muriatic acid with oxigene, the nitro-muriatic acid which results from this composition contains both acids, and they act each according to its peculiar nature, forming peculiar and distinct salts with all the bodies exposed to their action. It would therefore be a service of some importance to chemistry, to determine what quantity of the nitric acid is necessary to saturate a given quantity of the muriatic with oxigene, and to cause it to assume the character of nitro-muriatic acid, without containing any aquafortis, which only alters it and renders its effects uncertain. Hence it appears necessary, in recording accurate chemical experiments upon this matter, to mention the proportion in which the two acids have been mixed to produce the *aqua regia* made use of.

This mixed acid has less specific gravity than either of the two acids of which it is composed. It has a peculiar smell, commonly a citron-colour, often inclining to orange. Its action on natural bodies distinguishes it from all other acids. Light extricates from it a portion of oxigene gas or vital air. Heat separates

from it oxygenated muriatic acid. *Aqua regia* combines with water in any proportion, and always excites heat as it enters into combination with that fluid. It dissolves alumine, but very slowly : it unites with barytes, magnesia, lime, and the alkalis ; and from these combinations there result mixed salts, which crystallize either separately or together, according as they are more or less soluble. *Aqua regia* is much used both in chemistry and in the art of assaying ; as we shall show more at large when we come to speak of metallic substances.

Since the æra of Dr Priestley's discoveries, chemists have laboured much to discover the intimate nature and the component principles of the nitric acid. It was shown, in the first place, that the opinion which ascribed the formation of the nitric to the sulphuric acid, and represented the former as a modification of the latter, was founded on fallacious experiments. Soon after, it was observed, that this acid is formed of peculiar principles ; and the following observations led to a certain discovery of its nature.

The nitric acid had been long observed to act with great force on combustible bodies, more especially on the metals. On such occasions, it exhales into the atmosphere a considerable quantity of red vapours, and is often indeed entirely dissipated under this form. The combustible body exposed to its action is soon reduced to the state of a burnt body, or oxide ; nay, it often causes combustible bodies, such as oils, charcoal, sulphur, phosphorus, and several of the metals, to emit a sudden flame. Stahl ascribed this effect to the rapidity with which the acid combined with the phlogiston of combustible

combustible bodies. But this theory did not afford a satisfactory explanation of the phenomenon.

Dr Priestley, by receiving into a glass vessel filled with water, the vapour disengaged during the action of the nitric acid on a piece of iron, observed, that instead of a red vaporous fluid, a transparent colourless gas resembling air was obtained on that occasion; and to this he gave the name of *nitrous gas*.

This gas possesses all the apparent properties of air, but differs greatly from it in respect to chemical properties. It has rather less gravity, is unfit for maintaining either combustion or respiration, is strongly antiseptic, has no sensible taste, and takes a long time to alter the colour of syrup of violets. Nitrous gas appears to suffer no alteration from light. Heat dilates it. Vital air readily combines with it; thus reducing it to the state of nitrous acid. Atmospheric air produces the same effect upon it, but not so forcibly. This combination displays several phenomena which well merit our attention. As soon as air comes into contact with nitrous gas, though both the fluids were before colourless, they become instantly red like the nitrous acid: a pretty lively heat is then excited; the water rising in the receiver absorbs all these red vapours, and thus acquires the character of aquafortis. The purer the air is, the more readily do these phenomena take place, the more striking do they appear, and the smaller is the proportion necessary to change a given quantity of nitrous gas into nitrous acid. M. Lavoisier has discovered, that sixteen parts of atmospheric air are necessary to saturate seven and one-third of nitrous gas, while four parts of vital air are sufficient for the com-

plete saturation of the same quantity of the same gas. Macquer thought this beautiful phenomenon precisely similar to combustion. It is in fact accompanied with heat, the absorption of air, and the production of a saline matter; and the red colour which then appears may be considered as a kind of flame.

As in this artificial composition of the nitrous acid, the air produces different effects, according as it is more or less pure, Dr Priestley thinks that nitrous gas may serve as a test to enable us to distinguish what quantity of vital air any other kind of air contains; if we assume as two terms,—the most impure air, or gas unfit for respiration, such as the carbonic acid, which produces no change whatever on nitrous gas,—and vital air, which produces the greatest alteration upon it. This assay consists in employing known and proportional quantities of these two gases, and observing when they are mutually and completely saturated. That air is the purest of which the smallest quantity is sufficient to saturate a given quantity of the nitrous acid, and *vice versa*.

Several philosophers have endeavoured to find means for performing this experiment with the most rigid accuracy. The Abbé Fontana has been the most successful: he has contrived an *eudiometer*, of which an exact description is to be found in M. Ingenhousze's experiments on vegetables. By means of that instrument, the degrees of the purity or impurity of the air may be estimated with the utmost nicety; but, as the author himself acknowledges, such skill and attention are necessary in making use of it, that to avoid mistakes and erroneous calculations is exceedingly difficult.

It is farther of consequence to observe, that these experiments, though extremely ingenious and of considerable utility, have not been attended with all the advantages expected from them, in regard to that branch of medicine, the object of which is the preservation of health. They show what quantity of air fit for respiration is contained in that under examination; but they afford no information concerning the manner in which the noxious qualities of this fluid affect the several parts of the human system with which it is brought into contact by respiration: they explain not how it acts on the stomach, the skin, or the nerves; all of which are affected by almost every alteration of the air, though only medical observations can inform us in manner.

Chemists have for a number of years been divided in their opinions concerning the cause of the production of the nitrous acid from the mixture of nitrous gas with vital air. Dr Priestley, the discoverer of the fact, is of opinion, that nitrous gas is merely nitrous acid^f supersaturated with phlogiston; and that as pure air has a greater affinity than the acid with phlogiston, it therefore, entering into combination with it, leaves the nitrous acid in a state of liberty. But this theory is far from affording a complete explanation of the phenomenon: for when the elastic fluids with which the experiment is performed are very pure, there is absolutely no residue left; and besides, the nitrous acid formed during the process, weighs considerably more than the portion of nitrous gas which was made use of to produce it.

M. Lavoisier imagined that this property of nitrous gas—to produce nitrous acid, when brought into con-

fact with vital air, might lead him to a knowledge of the component principles of the acid. By combining two ounces of spirit of nitre of known strength, with a given quantity of mercury, he obtained 196 cubic inches of nitrous gas, and 246 cubic inches of vital air. While the former gas was disengaged, the mercury changed its form; after the vital air was disengaged, it returned to a metallic state, when it was found to have suffered no loss. From these facts he deduced the following inferences with great accuracy of reasoning. —1. As the mercury suffered no loss during the process, the formation of the elastic fluids cannot be ascribed to it. 2. These must therefore have been formed by the decomposition of the nitrous acid. 3. The nitrous acid made use of on the occasion, the gravity of which was to that of distilled water as 131,607 to 100,000, appears therefore to have been formed of three principles, nitrous gas, vital air, and water, united in the following proportions to the pound: nitrous gas, 1 ounce $5\frac{1}{4}$ grains; of vital air, 1 ounce 7 drams $2\frac{1}{2}$ grains; and of water 13 ounces and 18 grains. 4. Nitrous gas is nitrous acid deprived of its oxigene or vital air. 5. In all processes in which nitrous gas is obtained, the nitric acid is decomposed, and its oxigene absorbed, by the combustible body with which it has a greater affinity.

Yet this opinion is attended with one difficulty. M. Lavoisier found that he could not reproduce by the reunion of these products the whole quantity of the acid from which they were obtained; at least one half was entirely lost: and he had much more pure air than was necessary for the complete saturation

the nitrous gas. He acknowledges himself unable to account for this circumstance. Macquer imagined it to depend on the loss of the phlogiston, or light, which he considered as one of the principles of the nitric acid: this he thought might escape through the pores of the vessels during the decomposition of the acid, leaving behind part of its pure air, which being less subtle, could not make its way out with the same facility. We shall soon see this not to be the true cause of the phenomenon.

The portion of superfluous gas which remains after the nitrous gas has been saturated with vital air, still remained an objection against M. Lavoisier's theory. And though this superfluity was quite a trifle in this experiment, as $7\frac{1}{2}$ parts of nitrous gas, with 4 parts of vital air, left no more than $\frac{1}{14}$ th of their total bulk; yet still he was at a loss how to account for it. Indeed he has since informed us, that the residue was much less when the matters made use of were very pure and very nicely proportioned. In short, we shall immediately see that vital air and nitrous gas may be obtained so pure as to combine without leaving any residue.

No such difficulty occurs in considering the aëriiform residue formed by the combination of 16 parts of atmospheric air with $7\frac{1}{2}$ of nitrous gas: we know it to be the mephitic or gas azote contained in the atmospheric air. We understand likewise how the contact of water comes at length to alter nitrous gas and change it into an acid: it is by means of the air which it contains.

But even after this theory of M. Lavoisier's, the na-

ture of nitrous gas still remained unknown ; and it has since been explained by a fine experiment of Mr Cavendish's. This chemist put into a glass tube seven parts of vital air not obtained from the nitric acid, with three of gas azote or atmospheric mephitic ; and by causing the electric spark to pass through the mixture, he effected a great diminution of its bulk, and even changed it into nitric acid. The induction which he draws from these facts is, that the nitric acid is a combination of seven parts of vital air to three of gas azote ; and that, when deprived of a part of the first of these principles, as happens in the solution of metals, &c. it passes into the state of nitrous gas : Nitrous gas, therefore, is, in his opinion, nothing more than a combination of gas azote with a smaller proportion of vital air than what is requisite to form nitrous acid. These experiments, and the ingenious theory founded upon them, throw great light on the formation of the nitric acid by the putrefaction of animal matters. We know that a great quantity of gas azote is disengaged from these matters when putrefying ; and it is evident how necessary vital air is for the production of this acid, as experience shows it to be formed by the combination and fixation of these two elastic fluids.

It is also easy to determine the difference between the pure white acid of nitre and the coloured fuming acid to which the northern chemists give the name of *phlogisticated* ; or between the nitric and the nitrous acids. The last is found where the principles are not combined in the proportion proper for forming the pure nitric acid,—that is, when the combination consists not of three parts of azote and seven of oxygen.

gene. But as a variety of circumstances, and in general all *phlogisticating* processes, diminish the proportion of the oxigene, by wasting more or less of it, hence we may naturally infer, 1. That this acid is very liable to alteration, and must often be more or less coloured and fuming: 2. That in proportion as it is deprived of more or less of its oxigene, it may pass through many states, from that of the purest nitric acid, which contains the greatest proportion of oxigene, to nitrous gas, which contains not enough to constitute it an acid: 3. That if nitrous gas be deprived of what oxigene remains in it, it becomes gas azote or mephitis: 4. That as the mutual adhesion of the oxigenous and azotic principles is very trifling, most combustible bodies having a greater affinity with the former than the azotic principle has; the nitric acid cannot but be decomposed with great facility by many bodies. These four remarkable particulars in the history of the acid of nitre, serve to explain a great many phenomena. We now understand, 1. That in this acid the gas azote and vital air have lost much of their caloric, and are therefore reduced to azote and oxigene. 2. That when this acid is decomposed by a combustible body, the nitrous gas then disengaged does not require so much caloric to maintain it in a state of elastic fluidity, as vital air and gas azote. 3. That these two fluids cannot combine when in a gaseous state. 4. That of consequence the vital air obtained from nitrous preparations strongly heated, such as *red precipitate*, nitrate of lead, common nitre, &c. must contain a certain proportion of mephitis or azotic gas; of which gas, the residue, remaining after the union of the vital air

with

with the nitrous gas, consists. No such residue is ever observed to remain, when the vital air made use of, has been obtained from the leaves of vegetables or from manganese. 5. That the case is sometimes the same with nitrous gas; it may contain a portion of gas azote or mephitic: and this happens when this gas is prepared with bodies which, being very greedy of oxygen, absorb it almost entirely from the nitric acid; such as iron, oils, &c. 6. That the nitrous acid when coloured, and containing an excess of nitrous gas or of azote, or the base of mephitic, is in a state very different from that in which the two principles are no more than mutually saturated; and that as the difference between these two states of this acid is so very considerable, they should therefore be distinguished by different names. To the white acid, which, though the most uncommon, is the purest, we give the name of the *nitric acid*, observing the same analogy in this as in the rest of our new denominations; and to its neutral salts we give the name of *nitrates*. The red again we call *the nitrous acid*, and its saline combinations *nitrites*. There is indeed but seldom occasion to speak of the last of these classes of neutral salts: for though the red and fuming, or the nitrous, be the most common of the two acids, it very seldom retains its proper character when united with alkaline bases; the superfluous quantity of the nitrous gas usually escapes as the combination is taking place, and what remains is pure nitric acid.

The affinities of the nitric acid with the alkaline bases are the same as those of the muriatic; and Bergman arranges them in the same order, as follows,—

barytes,

barytes, potash, soda, lime, magnesia, ammoniac, aluminous earth. According to that celebrated chemist; the nitrous or *phlogisticated* acid has the same affinities as the pure acid of nitre. It is stronger than any of the preceding acids, and disengages the carbonic, fluoric, and muriatic acids, from their bases.

The acid of nitre, under the name of *aqua fortis*, is applied to a great many purposes in the arts; more particularly, it is used to dissolve mercury, copper, silver for hatters, engravers, and gilders, in assaying and working metals, &c. It is likewise used in surgery, to destroy warts and other little indolent uninflamed tumours. It is used in many pharmaceutical preparations, such as *mercurial water*, *red precipitate*, *the alkaline martial tincture*, *the yellow unguent*, &c. &c. We shall take notice of these and the other uses to which it is applied in their proper places.

Species V. *The Sulphuric Acid.*

THE sulphuric acid, which has hitherto been called the *vitriolic acid*, is a very caustic saline substance, which, when concentrated, burns and cauterizes the skin, reddens syrup of violets without destroying its colour, and when diluted in a large proportion of water, has a sour, stiptic taste. This acid, when pure, appears under the form of a very transparent oleaginous fluid, twice the specific weight of distilled water, destitute of smell, and united with water, from which there are as yet no means known of separating it. It has received the name of the *vitriolic acid*, because it used formerly to be obtained from martial vitriol by

Vol. I. B b distillation.

distillation. At present it is obtained both in France and England by the complete combustion of sulphur, as we shall explain more at large when we come to give the history of that combustible substance. Its nature, therefore, and the manner in which it is obtained, render it most proper to give it in a methodical and regular nomenclature, the name of the *fulphuric acid*.

When highly concentrated, it is from its consistency named very improperly *oil of vitriol*.

This acid is susceptible of a concrete form ; which it may be made to assume either by exposing it to cold, as we shall afterwards see, or by combining it with various elastic fluids.

We know not yet, in what manner light acts on the fulphuric acid. Some chemists have asserted, that when oil of vitriol is exposed in close vessels to the rays of the sun, it gradually assumes a colour, and there is even some sulphur formed. But this fact is not altogether established by proofs ; nay, there is even a strong probability against it ; for we shall hereafter see, that the fulphuric acid cannot become sulphur without losing its pure air or oxigene ;—and it is evident that such a separation cannot take place in close vessels.

Stahl thought the fulphuric acid to be diffused through all nature, and to be the principle of all other acids. The first of these assertions was founded on this fact, that linen impregnated with potash, and exposed to the air, is at length converted into sulphate of potash ; that is, into a neutral salt formed by the union of the alkali with the fulphuric acid. This assertion is at present known to be false ; for such linen contains not as

atom of sulphate of potash, but a good deal of carbonate of potash, or the combination of this alkali with the carbonic acid. With respect to the second, nothing can be more improbable. Late experiments have shown that each of the acids is formed of peculiar principles; and that there is no principle common to one with another of them, but the base of vital air, which is common to them all.

The sulphuric acid, when heated in a retort, soon loses part of its water, is in some degree concentrated, and is not volatilized unless exposed to a strong heat. If coloured, it loses its colour by the action of the fire, and becomes white. This *double* change which it undergoes at *one* time, is called the *concentration* and *rectification* of the acid. While it is taking place, a very odorous and penetrating gas is disengaged, which was the colouring principle of the acid, and with which we shall afterwards get acquainted under the name of the *sulphureous acid gas*. Although this process appear to render the sulphuric acid whiter and more pure, yet it must be carried farther when we wish to obtain the acid in its highest purity: in fact, in this ordinary concentration, we only free the acid of the water and the sulphureous acid gas united with it, without separating any of the fixed matters, by which it may likewise be altered: To effect this, we must distil the acid to dryness, by changing the receiver, after performing the first part of the operation: there remains then in the retort a small quantity of a white residue, which is found to contain sulphate of pot-ash, and some other substances which are dissolved in the acid as it is formed.

The concentrated sulphuric acid attracts moisture, when exposed to the air, and loses part of its strength and causticity : it at the same time assumes colour, deriving it from the combustible matters which float in the atmosphere, on which this acid acts with no small force. It often absorbs nearly twice its own weight of water from the atmosphere.

The Duke d'Ayen, by a series of curious experiments, performed during the violent cold in the month of January 1776, has shown, that this acid, when highly concentrated, may be made to freeze by exposing it to the cold temperature of from $61^{\circ} 15'$, to $65^{\circ} 45'$; but when diluted in two or four parts of water, is no longer liable to the same change of state by cold : and that if when frozen it be left exposed to the air, it soon becomes fluid, even though the cold be more intense than that which caused it to freeze. This last phenomenon is owing to its absorbing water from the atmosphere, and to the heat produced while the two are entering into combination.

The sulphuric acid unites with water, displaying, as it enters into union with it, all the phenomena of a sudden penetration and an intimate combination. It produces at the same time a lively heat and a sort of hissing ; a peculiar fetid odour is likewise disengaged. The hissing noise excited on this occasion is owing to the disengagement of the air contained in the water, which is seen to make its way out in the form of little bubbles. The taste of the acid, when thus diluted in water, is much weaker than in its concentrated state, its fluidity is much more considerable, and it now bears the name of *spirit of vitriol*. The water may be volatilized by heating it;

it ; and it may be thus restored by concentration to the state of concentrated sulphuric acid.

This acid acts not in any manner on siliceous earth or quartzose stones, nor on the same earth when melted with the admixture of small pieces of the fixed alkalis. It combines with aluminous earth, barytes, magnesia, lime, and alkalis. In these combinations it forms aluminous sulphate, or *alum* ; barytic sulphate, or *ponderous spar* ; sulphate of magnesia, or *Epsom salt* ; sulphate of lime, or *selenite* ; sulphate of potash, or *vitriolated tartar* ; sulphate of soda, or *Glauber salt* ; and ammoniacal sulphate. Its elective attractions for these salts are the same with those of the muriatic and the nitric acids ; but it adheres more firmly to these substances than any of the other mineral acids ; and is capable of disengaging them.

The action of the sulphuric on the other acids has not as yet been properly examined ; we know only,

1. That it absorbs great quantities of the carbonic acid,
2. That it unites so readily with the muriatic acid, that when we mix the two together, heat is excited, and a great quantity of muriatic acid gas is disengaged in white vapours. Boerhaave, in his Chemistry says, that the muriatic acid renders *oil of vitriol* concrete : perhaps this property may be found to belong to the oxygenated muriatic acid.
3. That if the pure white nitric acid be poured on a quantity of sulphuric acid blackened by some combustible body, it deprives it of its colour, and renders it transparent ; and when this mixture is heated, it exhales a quantity of nitrous gas.
4. That nitrous gas when united with this acid, has the power of making it assume a concrete form ; as

will be shown more particularly in the article of the decomposition of nitrate of potash by means of sulphate of iron.

The manner in which the sulphuric acid acts on combustible bodies, leads us to an idea of its nature and component principles. Whenever any combustible body, such as a metal, or still more a vegetable or an animal matter, is brought into contact with the concentrated sulphuric acid, that body passes sooner or later into the state of a burnt matter, and the acid is decomposed.

All matters containing oil, become black, if immersed in sulphuric acid concentrated and cold. The acid first assumes a brown colour, which soon passes into a black. If an inflammable substance in combustion, such as a burning coal, be immersed into a quantity of sulphuric acid, the acid immediately assumes the smell and volatility of burning sulphur; a white smoke arises from it, of a lively suffocating smell. If, in order to comprehend better what passes when these combinations take place, we bring this acid into contact with some combustible body of a more simple character than organic substances, whose alterations may be more easily traced and estimated, we may then attain a knowledge of the principles of the sulphuric acid. If we heat for this purpose a mixture of this acid concentrated, with mercury, in a glass retort, the extremity of which enters a bell-glass filled with this metallic fluid; as soon as the acid is brought to boil, it emits a permanent gas of a strong pungent smell, resembling that of burning sulphur.

The aëriform fluid is known by the name of
sulphureous

fulpbureous acid gas : it is somewhat more ponderous than air ; it extinguishes light, kills animals, reddens and discolours syrup of violets. According to Dr Priestley, it enters into combination with water with less rapidity than the muriatic acid gas ; it dissolves chalk, camphor, and iron ; coals, and all bodies that are porous in any considerable degree, absorb it. Though it has been considered as a permanent gas, yet by the application of an intense cold, it may be condensed so as to become liquid. M. Monge accomplished this..

The sulphureous is a certain modification of the sulphuric acid, which combines with the alkalis to form neutral salts different from those which they form with the latter. Stahl, who had observed all of these important phenomena with great attention, thought, that in this instance the phlogiston of the metal, uniting with the acid, communicated to it odour, volatility, &c. But as that great chemist did not carry his experiments far enough, he could not foresee, that a strong objection against this doctrine might be drawn from the very fact on which it was founded. M. Lavoisier, M. Bucquet, and myself, have each of us examined the consequences of this reciprocal action of mercury and the sulphuric acid. When the mixture is white and dry, but a very small quantity of sulphureous acid gas is formed ; if this mercurial sulphate be then strongly heated, a little water, and a gas quite different in nature from the former, are disengaged ; the gas is very pure vital air. While this gas escapes from the mixture, the mercury is gradually *reduced*, and regains all its original properties, not so much as an eighth part of its quantity being lost. From this it appears, that

as the mercury has suffered no alteration, the two gases must belong both to the sulphuric acid which has been decomposed. The sulphureous acid gas appears therefore to bear the same relation to this acid which the nitrous bears to the nitric acid. Yet the composition of these two acids is not made quite in the same manner ; for we cannot instantly re-unite the two gaseous principles of the sulphuric acid into the compound body from which they are obtained ; whereas we can form the nitrous acid at pleasure, by combining the nitrous gas, and the vital air which it affords when analysed. It is very likely that a considerable space of time is necessary for the recombination of the sulphuric acid : for this phenomenon actually takes place when we expose to the air compounds of the sulphureous acid with different bases, these being at length found to contain sulphuric acid. Thus the combination of the sulphureous acid with potash, known under the name of *Stahl's sulphureous salt*, or sulphite of potash, if exposed to the air, becomes at the end of a certain time genuine sulphate of potash. What, in these instances, is slowly effected, takes place with more rapidity in the combustion of sulphur ; during which that combustible body absorbs the oxigene of the atmosphere, and becomes gradually more and more acid, till it be completely saturated. (See the *History of Sulphur*.)

From these facts it appears, 1. That the sulphuric acid is a compound of sulphur and oxigene. 2. That when a combustible body having a greater affinity than sulphur with oxigene or the base of vital air, is mixed with

with it, that body decomposes the acid, by absorbing the oxigene. 3. That when the combustible matter does not carry off all the acidifying principle, as happens in most of the solutions of metals effected by the sulphuric acid, what is separated is not pure sulphur, but sulphureous acid gas. 4. That this gas is a kind of intermediate body between sulphur and the sulphuric acid; and is to be considered as differing from the acid, only by containing a smaller proportion of oxigene; from sulphur, only by containing so much oxigene as renders it faintly acid. To cause it to pass into the state of real sulphur, all that we need to do is, to drive off that portion of the base of vital air which it contains; as happens towards the end of the process in which metals are dissolved by the sulphuric acid, when these solutions are strongly heated and made to evaporate. We now likewise understand how the sulphureous is gradually converted into the sulphuric acid, by absorbing the oxigene of vital air contained in the atmosphere.

The sulphureous acid gas is capable of uniting in a very intimate manner with the sulphuric acid, and it then communicates to this acid the property of exhaling in thick white vapours. Meyer, in his Chemical Essays, on the article of Quick lime, mentions a *fuming oil of vitriol*, prepared at Northhausen in Saxony, from a distillation of *common vitriol*. He likewise follows Christian Bernhard, a German chemist, in mentioning a concrete fuming acid salt obtained from this acid by distillation. Finding an opportunity of procuring in Paris a considerable quantity of this sulphuric acid of Saxony, I observed it to possess the properties ascribed to it by Meyer, and obtained from it, by using a gentle heat,

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crystallized,

crystallized, concrete, volatile salt, fuming and deliquescent, under two different forms, according to Christian Bernhard's account of it. I am convinced, from various experiments related in a memoir of mine, read in the Royal Academy of Sciences in the year 1785. 1. That the property possessed by this black sulphuric acid of Northhausen, of fuming and affording a concrete volatile salt, depends on its containing a great quantity of sulphureous gas. 2. That in proportion as it loses this gas by being exposed to the air, it ceases to exhale vapours, and loses its power of affording concrete salt. 3. That water disengages this gas, and deprives the sulphuric acid of Saxony of its property of fuming, &c. 4. Lastly, That the fuming concrete acid salt obtained from this acid by distillation is a saturated combination of sulphuric acid with sulphureous gas, which when exposed to the air, gradually passes into the state of common sulphuric acid. We are therefore acquainted with two concrete sulphuric acids, one of which owes its concretion to nitrous gas, the other to sulphureous acid gas. I make no doubt but the number of concrete acids may be one day increased, by some other modifications of the sulphuric acid reduced to solidity by other gases; such as oxygenated muriatic gas, &c.

The sulphuric acid is made use of in many of the arts, more especially by the dyer and the hat-maker, &c. It is one of the most common and useful menstruums in the laboratory. In medicine it is externally applied as a very useful caustic, and internally as a refreshing, cooling, and antiseptic medicine; but in this case, it must be diluted in water till it have scarce any sensible acidity.

The sulphureous acid is used in dyeing, for whitening silks, taking out stains, &c.

As these two acids are combinations of sulphur and oxygen in different proportions, their names ought to be analogous to their nature: to us they appear to be best distinguished by the names of the *sulphuric acid*, and the *sulphureous acid*. The termination of the word *sulphureous*, serves in this, as well as in other instances, to show that the acid to which it belongs contains an excess of the combustible base *.

Species VI. *The Boracic Acid.*

EXPERIMENTS made by a great many chemists have shown borax to be a neutral salt formed by the combination of soda with a peculiar acid: this acid was called by Homberg, its discoverer, *sedative salt*. It has been since named the *acid of borax*, and the *boracine acid*; we choose rather to call it the *boracic acid*, in order that its name may terminate in the same way as the names of the other acids.

Many chemists have thought this acid to be merely a product of art formed by the combination of the salts used in obtaining it with some principle of borax: But since M. Hoefer, apothecary to the Grand Duke of Tuscany, has discovered that the waters of several lakes in that country, for instance, those of Castelnovo and Monterotondo, maintain in solution a considerable quantity of
very

* The sulphuric acid is found, disengaged, in nature, in some parts of Italy. Baldassari has observed it, in this state, in a grotto in Tuscany, at St. Albino, and at the lakes of Travale. Vandelli relates that sulphuric acid is sometimes found dissolved in water, in the environs of Sienna and Viterbo. M. Dolomieu found it in pure crystals in a grotto on Mount Etna.—H.

very pure boracic acid ; we can no longer entertain a doubt of its being a peculiar acid. The chemists of the academy of Dijon have confirmed this discovery ; on examining a quantity of water from the lake Monterotondo sent them out of Tuscany, they found it to contain the salt which M. Hoefer had ascribed to it. It is very likely that the same salt may be found in other mineral waters : it appears, as we shall hereafter mention, to be formed by the putrefaction of fat bodies.

The boracic acid, whether native or obtained from borax, by processes which we shall have occasion to describe under the article of that neutral salt, is a concrete matter, crystallized in small white scales, very thin, irregularly formed, figured round their edges, extremely light, and sometimes glittering. It has a weak, yet a sensibly acid taste. It communicates a faint red to tincture of violets ; but has a much stronger effect on that of turnsol, mallows, raddishes, &c.

When exposed to heat, it is not volatilized ; but it melts when made red hot into a transparent glass ; and the glass becomes opaque, and is covered with a light white dust when exposed to the air. This glass is the boracic acid unaltered ; it regains its lamellated form when dissolved in water, and caused to crystallize.

The boracic acid suffers no sensible alteration from the action of the air, whether it be dry, or moist, hot or cold.

It dissolves in water, not without difficulty ; for, according to the academicians of Dijon, a pound of boiling water dissolves no more than 183 grains of this acid ; when cooled and partly evaporated, it returns to its crystalline form. This solution instantaneously red-
dens

dens the tincture of turnsol, and alters, though more slowly indeed, the colour of syrup of violets. When a quantity of the boracic acid, moistened with a little water, is heated in a cucurbite, fitted with a capital, part of the acid is sublimated together with the vapour arising from the water; but as soon as the whole of the water is volatilized and the boracic acid left dry, the sublimation ceases: from which it appears that the acid is of itself fixed, as may be shown by melting it in a crucible. By sublimating it in this manner with water, if the process be skilfully conducted, it is obtained under a beautiful sparkling crystalline form. The boracic acid, after passing through this process, is very pure, and is known in pharmacy by the name of *sublimated sedative salt*.

The boracic acid serves as a flux to siliceous earth; and the glass which they form together is white or faintly coloured. With the help of heat, it dissolves the earth precipitated from the liquor of flints. It unites with barytes, magnesia, lime, and alkalis; and forms by its union with these substances a class of peculiar salts, distinguished by the general name of *borates*, of which we are well acquainted with none but one species.

The whole of these properties, but more especially its taste, and the red colour which it communicates to blue vegetable tinctures, sufficiently distinguish it as an acid. But it saturates alkaline bases only in part; and is known to be the weakest of all acids, as all of the others, not even the carbonic acid excepted, disengage it from the substances with which it combines.

The

The action of the other acids on the boracic is not well known. It appears to effect a partial decomposition of the sulphuric acid ; for when distilled on this salt, the sulphuric passes into the state of sulphureous acid. As to the nitric and the muriatic acids we know that they dissolve it ; but the phenomena which take place on that occasion have not yet been sufficiently attended to, to enable us to determine whether or not a mutual decomposition then takes place.

A diversity of opinions prevails concerning the nature and the formation of the boracic acid. A number of chemists have believed it to be an intimate combination of the sulphuric acid, and vitrifiable earth with a fat matter. Messrs Bourdelin and Cadet think it to be formed by the muriatic acid. The latter of these two gentlemen thinks that it must contain a small quantity of earth of copper, because it has the same property with the oxides of copper, of communicating a green colour to the flame of combustible bodies. Cartheuser assures us, that on drying and calcining by the action of a slow fire, a quantity of the boracic acid in a state of great purity, he observed it to emit vapours of the muriatic acid ; and that on dissolving this salt thus dried, and filtrating the solution, he found a grey earth remaining after the filtration ; and lastly, that by many repetitions of this calcination and solution, he at length accomplished the entire decomposition of the boracic acid, and found it to be a modification of the muriatic acid fixed by an earth. This experiment has been repeated by Messrs Macquer and Poulletier de la Salle ; they observed an odorous vapour to be disengaged

ed during the calcination of this salt, but they were not able to distinguish from its smell that it was muriatic acid. By repeated deficcations and solutions, they obtained a small portion of grey earth; but the earth, when united with the muriatic acid, did not form sedative salt, as Cartheuser had given out; and of consequence this chemist's opinion appears to be no better supported than the rest. Model thought this salt to be a combination of a peculiar alkali with the sulphuric acid, which is used in disengaging it. But this opinion cannot be admitted; for the boracic acid is always the same, whatever be the acid used to precipitate it. M. Baumé says, that he found means to produce the boracic acid by leaving a mixture of grease and clay to macerate for 18 months. At the end of that time, he obtained from it, by lixiviation, a salt in small scales, with all the properties of *sedative salt*. From this he concludes the boracic acid to be a combination of the acid of grease with a very fine earth, which it is impossible to separate entirely from it. He adds, that the same salt may be produced with vegetable oils, but more slowly. M. Wiegleb repeated M. Baumé's experiment, but without obtaining boracic acid.

Chemists at present think this to be a peculiar acid differing from all others, and possessing certain characteristics of its own. Its elective attractions for alkaline bases are arranged by Bergman in the following order; lime, barytes, magnesia, potash, soda, ammoniac. As they differ greatly from those of the other acids above-examined, they afford an additional proof
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of the peculiarity of the nature of this acid, whose component principles remain still unknown.

The use of the boracic acid in medicine, was first introduced by Homberg, who ascribed to it quieting narcotic qualities, and gave it the name of *sedative salt*, or *volatile narcotic salt of vitriol*, because he had obtained it by sublimating a mixture of *nitre* and *vitriol*. But experience has since shown the medical virtues of this salt to be but very moderate; at least it must be given in a much stronger dose than Homberg has directed, in order to produce the effects he ascribes to it; and it is very properly rejected, as we have many other medicines of the same class, whose effects are much more certain.

It is used in many operations of chemistry, and in the assaying metals as a flux. We will speak of its application to this purpose in a subsequent chapter*.

C H A P.

* The water of the lake Cherchiajo, near Monterotondo, in the Lower Siennese, afforded to M. Hoefer, three ounces of pure acid of borax, out of an hundred and twenty pounds of the water: 12,280 grains of the water of the Lake of Castelnovo, afforded 120 grains of pure boracic acid. Some pure boracic acid was collected in the mines of Tuscany by M. Besson. Mr Westrumb found borax in the *cubic* quartz of Limeburg — H.

C H A P. V.

ORDER II. SECONDARY, or NEUTRAL SALTS.

UNDER the name of *secondary salts*, are comprehended all such substances as are formed by the combination of two primary saline matters. They have received the name of *neutral salts*, because they possess not the characteristics of primary salts; that is, they are neither acid nor alkaline. Yet several of them, such as borax, chalk, and alkalis when united with the carbonic acid, exhibit, though in an inferior degree, some of the properties of primary salts. These secondary salts have not so strong a taste as most of the primary; nor do they dissolve, or enter into new combinations so readily. But, what principally distinguishes them from the primary is, their inability to communicate saline properties to other bodies. Their crystalline form is another characteristic by which they are distinguished; it merits the attention of the

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naturalist; but, though it sometimes determines their nature, it also occasions frequent mistakes.

The term *base*, is commonly used to denote the more fixed part of the composition of neutral salts. As this basis, which is sometimes volatile, communicates several pretty uniform general characteristics to the various combinations with acids, of which it admits, we shall use the name of the *base*, to distinguish the genera of secondary salts. These salts may then be divided into so many genera as there are saline or alkaline bases capable of being united with acids.

The first genus comprehends all such as are formed by the union of the two fixed alkalis with any of the acids. These we shall denominate *perfect neutral salts*; because the union of their component parts is very intimate:

The second genus includes those salts which are formed by the combination of volatile alkali, or ammoniac with acids. They have received the name of *ammoniacal salts* from the modern name of their base. They may also be called *imperfect salts*, because they are much easier decomposed than those of the former genus.

In the third genus are ranked such as have lime for their base. These are in general more imperfect than those of the second genus, although lime has a stronger affinity than ammoniac with the acids, as will be afterwards particularly shown. They are denominated *calcareous neutral salts*.

The fourth genus consists of combinations of magnesia with various acids. These salts are still more easily

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fly decomposed than those of the last mentioned genus; because acids have a stronger affinity with lime and alkalis than with magnesia. Their proper name is *magnesian neutral salts*, or *neutral salts with a base of magnesia*.

To the fifth genus belong those of which the base is pure argillaceous or aluminous earth. Alum being the chief of these combinations, they have received the generic name of *aluminous salts*. Aluminous neutral salts are almost always decomposed by the operation of alkalis, lime, and magnesia.

Lastly, To the sixth genus we assign neutral salts, having a base of barytes or ponderous earth. Both these and the greater part of the two preceding genera are but very little known. *Barytic salts* is the distinctive name of this genus.

It may be easily imagined, that these several bases, when combined with the acids whose properties we have examined, must afford a very considerable number of neutral salts: and this number will be much more considerable, if, with Bergman, we admit as distinct salts the various combinations of these same bases with those acids which he calls *phlogisticated*; and which, according to the modern doctrine, are deprived of a part of their pure air or oxigene. But as these compounds are liable to alterations on coming into contact with air, which causes them almost instantly to assume the character of real neutral salts, it seems improper to add them to a list which is already but too numerous; we shall, however, point out what peculiar properties they acquire from the state of their acids. We

must observe farther, that although the alkaline bases here enumerated, when combined with aqua regia, afford a mixture of nitrous and marine salts, yet as these may be obtained separate, and are perfectly the same with those produced by the simple acids; we mean, therefore, to take notice of them only when speaking of the combination of alkaline bases with the simple acids. Having hitherto examined no more than six principal acids, we are to treat only of the neutral saline combinations into which these enter.

In the arrangement of the several species of the neutral salts, the most natural order seems to be that of the affinities of the acids: and, therefore, through all the genera, we begin with sulphatic salts, proceeding from them to the nitric; after which we treat successively of those whose bases are combined with the marine, the boracic, the fluoric, and the carbonic acids, the last of which is the weakest of all.

That our nomenclature may be clearly expressive of the nature of the substances to which it refers, the name which we affix to each of these salts is compounded of the name of its acid and that of its base; and the various names by which any neutral salt has been known at different periods are carefully subjoined.

Genus

Genus I. *Perfect Neutral Salts, or Salts with a base of fixed Alkali.*

Species I. *Sulphate of Potash.*

SULPHATE of potash, which has been also called *vitriolated tartar*, *Sal de duobus*, *Polychrest salt*, and *Arcanum duplicatum*, is a perfect neutral salt, resulting, as its new name denotes, from the combination of the sulphuric acid with potash. It seldom appears in the mineral kingdom; but a few vegetables contain a small quantity of it.

This salt is generally in a greater or a less degree transparent and regular; its crystals differ in form and magnitude, according to the circumstances in which they are obtained. When formed slowly in the small way, they assume the figure of transparent six-sided pyramids, nearly similar to rose-diamonds; and sometimes, though less frequently, they take the form of six-sided prisms, terminating in two hexahedral pyramids, much like rock crystal. But if the evaporation be very rapid, the crystals are agglutinated into one mass, under the form of a solid crust, the surface of which is covered with small irregular pyramidal spikes: of this kind is the salt of this name met with in commerce. Lastly, when, in order to obtain the crystals as regular as possible, a solution of this salt is exposed to a gentle spontaneous evaporation by the heat of the atmosphere, its crystals are generally solid twelve-sided figures, joining at the base, and sometimes separated by a short six-sided prism. These indeed are usually foul, and at no time

equal the whiteness and transparency of those which are obtained by the former process of evaporation. But one imperfection attending most of these neutral salts is, that they are either of a dark colour or an irregular figure.

Sulphate of potash has a very disagreeable bitter taste. Fire produces but little alteration upon it. When laid on burning coals, it breaks with noise into a number of little pieces: This phenomenon, which is called *decrepitation*, arises from the sudden rarefaction of the water which entered into it when it was crystallised. But sulphate of potash loses none of its essential properties by decrepitation. It decrepitates in the same manner when exposed to the action of fire in a crucible, and becomes dry, friable, and even pulverulent, by losing the water which it contained: it becomes red before melting, and a strong fire is requisite to bring it to fusion. If exposed to cold when in a state of fusion, it becomes an opaque mass, friable, and soluble: it appears likewise to have suffered no alteration of its principles; for it regains its transparent and crystalline form on being dissolved in water. If kept for a while in the state of fusion in an open vessel, it is volatilised, but without being decomposed.

Sulphate of potash suffers no alteration from air. It remains in its crystalline state, without suffering any change either of form or of transparency. It is scarce soluble in water; yet the difficulty of dissolving it is greater or less according to the temperature of the fluid. According to Spielman, about 18 parts of cold water are required to dissolve 1 of this salt. But boiling water dissolves it nearly in the proportion of 4 to 1;

for M. Baumé assures us, that 4 ounces of boiling water dissolve 7 drams and 48 grains of sulphate of potash. It is crystallised partly by cooling, but still more by evaporation : It contains but very little water in its crystals, and therefore suffers no change of state when exposed to the air.

Sulphate of potash acts not at all on the simple earths. When accidentally mixed with salts used as fluxes in making glass, it is found again in the scoræ; and it is obtained in considerable quantities from glass gall.

According to Bergman, barytes or ponderous earth having more affinity than potash with the sulphuric acid, decomposes this neutral salt. If a solution of this earth be poured on a solution of sulphate of potash, this process forms a precipitate of barytic sulphate or *ponderous spar*, which is absolutely insoluble; its properties we shall hereafter examine. The potash, if pure and caustic, remains dissolved in the liquor.

Lime and magnesia act not on sulphate of potash; but many of the acids act very forcibly upon it. Rouelle discovered that it is possible to combine with this salt a greater quantity of the sulphuric acid than it naturally contains. His process consists in distilling a quantity of concentrated sulphuric acid on sulphate of potash. The neutral salt becomes impregnated with the acid, and acquires new properties : it now reddens the tincture of violets, is soluble in water, has a sour taste, and effervesces with alkalis saturated with carbonic acid, even after being dissolved and crystallised. M. Baumé has maintained, that no real combination takes place between the acid and the neutral salt, and that they may be separated merely by placing them on

bibulous paper or sand. But Macquer remarks, that the sulphuric acid adheres with no inconsiderable force to sulphate of potash ; and thinks that their mutual adhesion must be owing to a peculiar affinity between the two substances : according to him neither fire nor water is able to separate them. I have several times combined the concentrated sulphuric acid with sulphate of potash, in Rouelle's way ; that is, by distillation in glass retorts, and have observed some phenomena not mentioned in his dissertation on the subject. Sulphate of potash melts on the occasion into a kind of glass or opaque white enamel of a strong acid taste : but this vitreous frit does not attract moisture from the air ; on the contrary, it rather exhibits appearances of efflorescence, when the acid makes only a fourth part of the total weight. There is, therefore, as Macquer thought, a pretty strong adhesion between the neutral salt and the acid ; and that adhesion is no doubt owing to a peculiar combination.

M. Baumé has observed, that sulphate of potash suffers a very considerable alteration from the nitrous acid. If aquafortis be boiled on this salt, the nitrous acid seizes on part of the potash, and disengages the sulphuric acid contained in it. When this mixture is suffered to cool, its crystals are pure nitre. It was at first thought that this decomposition could not take place without the help of heat ; but if fuming spirit of nitre be poured on sulphate of potash in powder, it will be found at the end of some hours to have deposited crystals of nitre. It was likewise advanced, that when the mixture became cold, the sulphuric acid, resuming its rights, decomposed in its turn the nitre of potash : but I have kept mixtures of sulphate of potash
with

with spirit of nitre for several years, and at the bottom of the mixture there were always saline crystals which detonized on burning coals, and suffered no change of nature though immersed in the sulphuric acid separated by the nitrous. M. Cornette has observed, that the concentrated muriatic acid likewise decomposes sulphate of potash, even cold. From these two facts it would appear, that the law of affinity respecting these different acids does not hold so invariably as was imagined. Yet we must observe, with Bergman, 1. That whatever quantity of the nitrous and muriatic acids be made use of in these experiments, no more than a third part of the given quantity of sulphate of potash is ever decomposed; while the sulphuric acid, when applied in a moderate proportion to nitrous and muriatic salts, effects a total decomposition of them: 2. That such a decomposition never takes place, except when the sulphate of potash contains rather more of the sulphuric acid than is necessary to constitute it a neutral salt. 3. That the affinity of sulphate of potash for the sulphuric acid, is the true cause of these decompositions, and that undecomposed sulphate of potash, is very acid.

But of all the modes of decomposition to which sulphate of potash is liable, the most worthy of our attention is that which it suffers from many combustibles, more especially from charcoal and several metallic substances (See my *Memoires de Chimie*, p. 225.). If a mixture of this salt with coal be strongly heated in a crucible, the sulphate of potash will be converted into sulphur united with the fixed alkali. Stahl thought this a very happy experiment for demonstrating the existence of phlogiston; modern chemists explain it by the pneumatic

matic theory. In the history of sulphur, we shall give both theories.

A quintal of sulphate of potash in crystals contains, according to Bergman, about 52 parts of potash, 40 of sulphuric acid, and 8 of water,—which last is necessary to make it crystallize.

As this salt is found but seldom in nature, and even then in small quantities, the sulphate of potash made use of in medicine is always a product of art. There are three ways of preparing it. First, by a direct combination of the sulphuric acid with potash. This instantly produces sulphate of potash, which may be dissolved in water, and crystallized, as we have mentioned above. The second way is, decomposing, by means of the sulphuric acid, neutral salts consisting of potash united with other acids; such as nitrate, muriate, and carbonate of potash, &c.: Sulphate of potash is infallibly obtained by all of these decompositions. The third way of forming this salt is by using potash to decompose earthy and metallic sulphuric salts. The potash precipitates the salino-terrene substances and the metallic oxides, and seizes the sulphuric acid. We will have occasion to take farther notice of the last two of these methods of preparing sulphate of potash, when we come to give an account of the neutral salts used in the preparation*.

This salt is not much used except in medicine. It is a pretty efficacious purgative. It is sometimes given by itself in dozes of half an ounce or an ounce.

But

* Mr. Chaptal relates, that he had occasionally obtained sulphate of potash from the analysis of tobacco.—H.

But it is most generally given, a dram or two at once, together with some other purgative medicines. It is used as a solvent in chronical distempers, particularly in coagulations of milk. It is then given in doses of a few drams together in certain preparations of liquids; but its solvent power is much inferior to that of many other neutral salts, which are more soluble and less nauseous.

The sulphureous acid, or the sulphuric with an overplus of sulphur, forms, when combined with potash, a salt somewhat different from that which we have been considering. Stahl called it *sulphureous salt*; we give it the name of *sulphite of potash*. This salt crystallizes in polyhædrons of ten sides, or in two tetrahædral pyramids cut towards their bases: it is very bitter, easily soluble, and rather deliquescent. Almost all mineral acids, and many vegetable acids, disengage the sulphureous acid from this salt with effervescence, and in a gaseous form. Sulphite of potash, when exposed to the air, gradually absorbs oxigene, and is converted into sulphate of potash *.

Species II. *Sulphate of Soda.*

SULPHATE of soda, which has been hitherto known by the name of *Glauber salt*, from the name of the German chemist who first discovered it, is a perfect neutral salt, formed, as its name indicates, by the union of the

* In opposition to facts above related by M. Fourcroy, M. Chaptal asserts, that in 1780, he himself shewed that the *nitric acid*, without assistance, will dissolve sulphate of potash; but that the sulphuric acid resumes its place, when the solution is concentrated by heat.—H.

the sulphuric acid with mineral alkali or soda. This salt possesses many properties in common with sulphate of potash, and some peculiar to itself. It is equally disposed to crystallize as the other; has a bitter taste; is scarce fusible; dissolves in water; is incapable of union with earths; and, like sulphate of potash, is decomposable in part by the nitrous and muriatic acids. Many of its properties, however, are considerably different from those of sulphate of potash; as we shall see by examining them particularly.

Sulphate of soda is commonly a body of a regular form, and more or less white or transparent. Its crystals are prisms with six unequal and striated sides terminating in dihædral summits. They are seldom under a regular form, and the number of the sides varies as well as their size, posture, and striæ; as M. Romé de Lille has shown very particularly in his crystallography. The prisms of this salt vary in size from the form of small needles, very minute, to prisms half an inch in diameter and six or eight in length; which last are obtained when a great quantity is crystallized at once. Its taste is at first fresh, but soon becomes very disagreeably bitter. It produces no alteration on blue vegetable colours.

When exposed to the action of fire, it is quickly liquefied: but it soon dries and becomes of an opaque white colour; in which state it is no less difficult to melt than sulphate of potash. In order to form a just notion of what passes when heat acts with this effect on sulphate of soda, we must take notice that saline substances are melted two ways. 1. By means of the water which enters into their crystals, which is called

aquous

aqueous fusion. This takes place only on such salts as are more soluble in warm than in cold water ; which happens because the portion of the fluid which enters into constitution of their crystals, being then warmed, dissolves the saline matter. This aqueous fusion is therefore nothing more than solution by warm water : and therefore sulphate of soda assumes again a solid form when it is suffered to cool. 2. But if the heat be continued after it is liquified, it becomes dry and white : it may then be melted by means of a more intense heat ; and this fusion is actually the effect of fire, and therefore called *igneous fusion*. Sulphate of soda is therefore no less difficult of fusion than sulphate of potash ; and like it is volatilized by the extreme violence of fire, but suffers no alteration of principles from the action of heat.

It is likewise on account of their containing a great quantity of water, that the crystals of sulphate of soda when exposed to the air, are in a short time reduced to a very fine white powder. This phenomenon is called *efflorescence* ; because in fact the crystals are covered over with a kind of fine flour, in whiteness and, form resembling the sublimated matters which are known in chemistry under the improper name of *flowers*. The cause of this salt's falling down in this manner, when exposed for some time to the air, is its losing the water on which the constitution of its crystals depends. It therefore effloresces most readily when the air is very dry, and of consequence eager to absorb moisture. This phenomenon, therefore, bears a great resemblance to the desiccation effected by heat : both depend on the evaporation of the water to which the crystalline

form is owing. Yet, as the water which enters into the crystals of sulphate of soda, and of all efflorescent salts in general, is perfectly combined with the saline matter ; efflorescence appears to be owing to a kind of elective attraction between air and water. This phenomenon is therefore to be considered as a decomposition of crystals, taking place in consequence of water's having a greater affinity with air than with the saline matter. Such has always been my idea of efflorescence, and I do not see how it can be explained otherwise, (See my *Memoires de Chimie*). Sulphate of soda loses almost half its weight when it undergoes this alteration : but its nature is not changed, and we may cause it to resume its crystalline form, by restoring to it the water which it has lost. Though no writer on the *Materia Medica* have as yet made the observation, yet to me, it seems an object of some importance, to know the exact quantity of water which sulphate of soda loses when it effloresces, in order that the same quantity may be always prescribed for a dose, in whatever of the two states the salt may happen to be. Rather more than one-third less of this salt should be given when it is in a state of efflorescence than when it is under the form of fine transparent crystals.

Sulphate of soda dissolves very easily in water. No more than four parts of cold water are necessary to dissolve one of this salt. But a smaller quantity of warm water will be sufficient to dissolve the salt, and a still smaller quantity in proportion as the water is made hotter. One part of boiling water dissolves almost as much of this salt as is equal to its own weight. The method in which we make it crystallise is founded on this

this property. As it is more soluble in warm than in cold water, all that we need to do is, to leave a strong solution of this salt to cool ; and it affords crystals which are more or less regular, and of a greater or a smaller size, in proportion as the quantity of the solution is greater or less, and as it is cooled more slowly or more quickly. In the laboratories of apothecaries, where this operation is performed in the great way, striated prisms several inches long are often obtained, which afford specimens of the regularity of the form of this salt.

Sulphate of soda acts no more on silice or alumine than sulphate of potash : and as it is so difficult of fusion, it is no more used in making glass than the other. Barytes decomposes it as well as sulphate of potash ; but the other salino-terrene substances produce no alteration upon it.

Pure caustic potash, mixed with a solution of sulphate of soda, decomposes it ; because it has a stronger affinity than soda with the sulphuric acid. In order to receive full conviction of this, the reader may pour a lixiviate of caustic potash on a warm and strongly saturated solution of sulphate of soda. This solution, which, if suffered to cool, would have afforded crystals of the latter, gives sulphate of potash by evaporation ; and the mother water contains caustic soda.

The sulphuric acid combines with sulphate of soda, and adheres to it in the same manner as to sulphate of potash.

The nitric and the muriatic acids decompose it with the same attendant circumstances as when they decompose sulphate of potash.

When sulphate of soda is violently heated with charcoal and some metals, the sulphuric acid assumes the form of sulphur, as we shall have occasion to mention under the history of that combustible body.

All the properties in which sulphate of soda differs from sulphate of potash, serve as so many proofs that the two fixed alkalis, however similar in their state of purity, are nevertheless extremely different from each other; because they form very dissimilar salts when combined with the same acid. Besides, the proportion in which the principles of this salt are united, is very different from that by which sulphate of potash is formed: for, according to Bergman, a quintal of sulphate of soda contains 15 parts of soda, 27 of sulphuric acid, and 58 of water *.

This salt is more copious in nature than sulphate of potash. It is obtained in great abundance from seawater, from the water of certain salt springs, and more especially from many mineral waters. Art can likewise procure it by the three methods of which we have given a description in the history of sulphate of potash. It is not more used in the arts than that salt; but much more in medicine. It is given as a solvent, aperient, and purgative, in doses of—from half a dram to an ounce and an half, according to the cases in which it is administered. Its effects are even more strong and quick than those of sulphate of potash; because its sapidity is greater, and it dissolves much more readily in the humours of the human body †.

We

* Others assert, that 100 grains of sulphate of soda contain 14 acid, 22 alkali, and 64 water.—H.

† The *tamarix gallica*, a plant growing on the sea coast of France, contains sulphate of soda in a large proportion.—H.

We are ignorant of the properties of sulphite of soda, or of that salt which is formed by the combination of the sulphureous acid with alkali of soda.

Species III. Nitrate of Potash, or Common Nitre.

NITRATE of potash, common nitre, or saltpetre, is formed by a saturated combination of the nitric acid with potash. This salt has a fresh taste, is a perfect neutral salt, and does not alter the colour of syrup of violets. Its crystals are six-sided prisms, terminating in dihedral pyramids, or cut off with a slope, and often channelled from one end to the other.

There is great abundance of this salt in nature : it is continually forming in places inhabited by animals. It is likewise found in abundance on walls sheltered from rain ; and is then called *saltpetre de bouffage*.

There seem to be three circumstances which chiefly promote its formation. The first of these is the presence of chalk, or some calcareous substance ; in this manner is the nitre formed which is gathered on walls covered with plaster ; and from this circumstance, considerable quantities of nitre are usually found on the demolition of old buildings. This salt is obtained in a state of perfect purity from chalky earths. The Duke de la Rochefoucault has obtained it in the proportion of an ounce to the pound from chalk of Roche-Guyon.

The second circumstance favourable to the production of saltpetre is the putrefaction or spontaneous decomposition of animal and vegetable matters. It is a well known fact, that places watered with animal liquors, or containing animal matters in a state of putre-

faction, such as dunghills, stables, jakes, afford great quantities of nitrate of potash. This fact has always been gone upon as a principle, in forming beds for the artificial production of nitre. Ditches or covered sheds are formed, and left exposed on all sides to the air: these are then filled with putrescent substances, such as dung of all kinds, and vegetable substances; water containing animal or vegetable matters is from time to time poured on the mass; and it is stirred now and then to change the relative disposition of the surfaces. When the putrefaction is considerably advanced, a small portion of the matter is taken and lixivated, in order that it may be known whether it contains nitre; and if it be found to contain a sufficient quantity of the salt, the whole mass is subjected to the same process.

The third circumstance apparently favourable to the production of nitre, is the contact of the air. This is one great cause of the formation of the saltpetre found on walls; and it is on this principle that the mixture deposited for the artificial production of nitre is frequently stirred, in order that the air may have access to every part of the mass. Beds of chalk, which naturally contain nitre, afford it only to a certain depth, and not lower. Where these three circumstances meet, nitre is produced in great abundance. Beds for the artificial production of nitre should be formed on these principles.

It is but a very short time since the theory of the production of nitre came to be known. Glauber, and a number of chemists who implicitly adopted his opinion, thought this salt to be entirely formed in vegetable substances, in them conveyed into the bodies of
animals,

animals, and by putrefaction only disengaged into a free separate state : But it was soon observed, that the vegetables used for its production in nitre-works could not be sufficient to afford, of themselves, the quantities obtained. M. Thouvenel, who by his essay on the formation of nitre gained a prize from the Academy, made a great many experiments with a view to discover its cause, and found that the nitric acid was formed by the combination of an elastic fluid disengaged from animal matters in a state of putrefaction with vital air. He has also shown that this acid, when formed, combines with calcareous earth, where nothing but animal matters is used for nitre beds ; and that the use of vegetable substances is to furnish fixed alkali or potash, which is the base of common nitre. M. Thouvenel had not determined the nature of the gas which is disengaged from animal matters in a state of putrefaction. And Mr Cavendish has since shown it to be the same with that which, under the name of phlogisticated air, atmospheric mephitic, or gas azote, constitutes one of the principles of the atmosphere. By combining this gas with vital air, by means of the electric spark, he obtained a product of genuine nitric acid.

Nitrate of potash is very liable to alteration from heat. When exposed to the action of fire in a crucible, it soon liquefies—by igneous fusion ; for though kept for some time in that state, it does not become dry ; and though made red hot, does not assume a pulverulent form. When suffered to cool, after being melted, it congeals into an opaque mass which is named *crystal mineral*, and is equally ponderous, fusible and soluble with nitrate of potash. The crystal mineral of the apothecaries shops

is somewhat different from pure melted nitre : for it contains a little sulphate of potash, produced by the combustion of sulphur, which, according to the Parisian pharmacopœia, is used in the proportion of a dram to the pound of nitre, in the preparation of it.

If nitrate of potash be left exposed to the action of fire, after being melted, it will be of itself decomposed and reduced to alkali. This operation succeeds equally well in a retort ; and when performed in this manner, is of use to explain the decomposition of the nitric acid. In fact, instead of the nitric acid passing off pure, there escapes a large quantity of an aëriform fluid, which may be collected under water, and is found to be genuine vital air mixed with gas azote. The residue of alkali usually melts the retort very soon after it is separated ; and when we wish to pursue the operation to a conclusion, we must use a stone retort which may be proof against its action. Here we have the nitric acid entirely decomposed into vital air and gas azote by means of heat, which alone is able to separate these two principles. If the heat be not continued so long, or made so intense, as to effect the entire decomposition of the nitrate of potash. The alkali still retains a certain quantity of the nitrous acid, or of the nitric with an excess of nitrous gas. This acid may be disengaged from it by vinegar. In this state, the salt is what we call *nitrite of potash*, the nitrous acid being supersaturated with gas azote ; in the same manner we called the combination of the sulphureous acid with potash, *sulphite of potash*. If nitrate of potash be acted upon by a very intense heat, a residue of pure caustic alkali is obtained. Since heat decomposes nitrate of potash

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with such facility, it may be naturally inferred, that when crystal mineral is prepared by simple fusion, the salt must not be too long exposed to the fire. If this precaution be neglected, the medicine will contain more than a just proportion of potash, and will produce too violent effects.

The decomposition of nitrate of potash is attended with other phenomena, when it is exposed to the action of fire, together with combustible bodies. When laid on a coal it gives a white lively flame, attended with a kind of decrepitation: this is called the *detonation, or fusion of nitre*: the salt is then said to detonize or melt; and by this characteristic, nitre may be at any time easily distinguished. Stahl thought this phenomenon to be owing to the rapid combination of the acid of nitre with phlogiston; and M. Baumé proceeding on the same theory, thought that in this operation a quantity of nitrous sulphur was formed, which was instantly inflamed. In the year 1780, I read in the Academy a Memoir, in which I have shown that nitrate of potash is neither combustible of itself nor yet forms nitrous sulphur when it detonizes; and that this phenomenon is entirely owing to the slower or quicker combustion of the combustible matter necessary to make the salt detonize, in consequence of the disengagement of the vital air, which escapes in great abundance from nitrate of potash strongly heated. This theory is completely proved: 1. Because the salt never detonizes by itself. 2. Because after its detonation by means of an inflammable matter, this matter is found to be entirely burnt up. 3. Because the greater the quantity of the nitrate of potash in proportion to

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that of the combustible matter, the more complete is the combustion of the latter substance. 4. Because detonation takes place as well in close vessels as in the open air, which could not possibly happen if the salt did not furnish vital air. This assertion receives the fullest support from the phenomena attending the process for making the *clyffus* of nitre; which is merely a detonation of this salt with different combustible matters in close vessels. We shall mention here only that which is made with charcoal. Two or three large receivers fitted together are applied to a retort of earth or iron, with an orifice in the upper part, which may be closed with a cover or stopper. This vessel is heated till its bottom be made red, and then a mixture of nitrate of potash with coal is put in by the orifice, which is immediately shut. During the detonation, the receivers are filled with vapours, part of which is condensed into an insipid liquor, not at all acid, but often alkaline. The residue is potash saturated with carbonic acid: the nitric acid is then totally decomposed, and a large quantity of gas is produced, which I have collected by fitting to the orifice in the upper part of the receivers, either a bladder or tubes, the extremities of which entered glasses full of water. This gas was mostly carbonic acid mixed with a little inflammable gas and gas azote; the last of which is one of the principles of the nitric acid. The inflammable gas is produced in consequence of the decomposition of part of the water of nitre by the charcoal.

The residue, after the detonation of nitrate of potash with charcoal in a crucible, is improperly called
nitre

nitre fixed by charcoal: it is potash combined with carbonic acid.

Nitrate of potash, when very pure, suffers no alteration from the action of the air.

It is easily soluble; for three or four parts of boiling water dissolve one of nitre, and boiling water dissolves a quantity of it equal to twice its own weight. It therefore crystallises very readily by cooling. On its possessing these two properties is founded the art of extracting nitrate of potash from plaster or rubbish containing it. The saltpetre-makers put the pounded plaster or rubbish into a vessel with a hole at the bottom, and cover it with ashes. Through this matter they pour water; taking care to pour pure water on rubbish that has been already washed, till it be deprived of all the nitrous matter it contains; and pouring water already impregnated with nitre upon the unwashed rubbish, in order that it may be completely saturated. They next evaporate the lixivium thus formed in copper vessels. They skim off the first pellicles, which are only the muriate of soda or marine salt contained in the rubbish. This salt they called *grain*; and by their regulations, they are obliged to carry it to the refining houses. When the water is evaporated to such a degree, that the residue when cool must become solid, they put it into other vessels in which the nitrate of potash is crystallized. This salt, which is very impure and dirty, is called *nitre of the first boiling*. Some chemists have been of opinion that the ashes used in making saltpetre served only to cleanse the nitrate of potash of certain greasy impurities; and that opinion appeared to be supported by the fact, that these matters con-

tain hardly any alkali, and the ashes of tarmarisk, used by the salt-petre makers of Languedoc, contain only sulphate of soda. But this salt, as well as sulphate of potash, is as useful as an alkali for decomposing the calcareous nitrate, which is found in such abundance in plaster and rubbish, by the way of double elective attraction, as M. Lavoisier has observed with respect to the lixiviated ashes used by the saltpetre makers of Paris. We shall say more upon this under the title of *Calcareous Nitrate*.

Nitrate of potash of the first boiling is always very impure. It contains five other kinds of salts beside pure nitre; namely, muriate of soda, nitrate of magnesia, calcareous nitrate, muriate of magnesia, and calcareous muriate; and these must be separated, if we wish to obtain nitrate of potash in a state of purity. The mixture is purified of these salts, by dissolving it again in the smallest possible quantity of water, and clarifying this boiling liquor by means of bullock's blood, which carries off all impurities by collecting them on the surface in the form of a scum. This lixivium is then evaporated, and by cooling the residue, a nitrate of potash is obtained, much purer than the former, which is said to be *nitre of the second boiling*. Still, however, it is vitiated by a certain quantity of muriate of soda and mother-water. It is a third time purified by the same process, and it then becomes much purer and whiter; and is now *nitre of the third boiling*. As it is made to crystallise very rapidly, it is obtained in large irregular masses; and yet in the middle of the vessels there is formed a layer of long regular crystals, which is called *nitre in sticks*. Nitre

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under this last form is not used in arsenals, being not so fit for making good gun-powder as nitre in large irregular masses; because the water which entered into it when it was crystallized would retard the combustion of the powder.

Chemists and apothecaries go on to purify nitre of the third boiling by new solutions and crystallizations. By this means they are certain of at length obtaining very pure nitrate of potash, entirely free of every extraneous mixture, and containing no muriate with either soda, lime, or magnesia for its base: Though these are scarce ever entirely taken away where the operation is performed in the great way *.

Nitrate of potash appears to be liable to some alteration from filiceous earth; for by distilling it with sand the acid is separated. This acid comes off colourless, but some vapours are diffused at the time. The residue is vitreous in a greater or a less degree, according as there was a greater or a less quantity of sand employed, and as the heat was weaker or more intense. Sand appears to decompose nitrate of potash by its tendency to combine with its alkaline base: for when nitre is distilled,

* There is no more extraordinary natural or chemical fact than the production of six species of salt, in the rubbish of old houses, each of the alkaline bases being constantly united with a peculiar acid. Potash is always united with the nitric acid, and soda is always combined with the muriatic. There would seem to be some particular relations between those different kinds of primary salts, in consequence of which they mutually select each other; for why is there no muriate of potash or nitrate of soda? The same thing might be observed of the earthy salts: in fact, there is much more muriate of magnesia and calcareous nitrate, than nitrate of magnesia or calcareous muriate: and this shows magnesia to have a peculiar affinity with the muriatic, and lime with the nitric acid.—F.

tilled, without any intermediate body being used, there is no nitrous acid, but a mixture of vital air with gas azote, obtained. The reason of this I take to be, that when nitre of potash is distilled without an intermedium, the alkali reacts on the acid, and contributes to its decomposition; whereas, when this salt is heated with a mixture of sand, the sand, by its tendency to form glass by combining with the potash, prevents the alkali from reacting on the acid, which therefore escapes unaltered. Argillaceous earths likewise decompose nitre. Coloured clay is generally made use of for this purpose. The distillers of aquafortis in Paris make use of an earth of this kind. Into earthen retorts, of a peculiar form, called *cuines*, they put into each two pounds of nitre, of the second boiling, with six pounds of coloured clay of Gentilly: the retorts are arranged one beside another, in long furnaces known by the name of *galleries*; and the neck of each retort enters a bottle of the same form, serving as a receiver. By this means they obtain at first a transparent liquor, somewhat acid, which they call *phlegm of aquafortis*, and afterwards the acid gradually more and more concentrated. The residue is a very hard, red, earthy substance, which serves for making a kind of mortar. But this experiment by no means proves that clay decomposes nitre of potash:—For, 1. The nitre used by the distillers is very impure, containing a great deal of earthy nitre: 2. The clay which they make use of is of a very compound nature, often containing a great quantity of pyrites, the sulphuric acid of which may possibly decompose the nitre. In order that this decomposition may determine the fact in question, it should be made with

white

white clay, or rather with alumine. As this earth has not so great a tendency as sand to unite with the alkali and does not form glass by combining with this salt, it does not seem capable of effecting so complete a decomposition of nitre of potash as sand produces. M. Baumé, however, says, that he obtained the acid of nitre of potash by the addition of porcelain and clay baked in stoneware: but he thinks that the decomposition of the salt was owing to the acid contained in the clays.

Barytes decomposes nitre of potash, and separates the alkali. Bergman, in his table of affinities, places this salino-terrene substance before the alkalis, and immediately after the nitric acid.

Magnesia, lime, and the alkalis, act not upon nitre. But the acids act in a very distinct manner on this salt, particularly the sulphuric acid, which has really a greater affinity than the nitric acid with the alkalis. When a quantity of concentrated sulphuric acid is poured on a quantity of dry nitre of potash, a considerable effervescence is produced, and red vapours are seen to arise, which are actually nitrous acid. By performing this operation in a receiver with the retort fitted to it, we may collect this acid: it is known by the name of *spirit of nitre*. This operation is called in the laboratories, *the distillation of the spirit of nitre in Glauber's way*; because Glauber was the first who gave a plain intelligible description of it. The receiver used in this operation must be perforated with a small hole, to give vent to the vapours of the nitrous acid. It was remarked, that there was much difficulty in condensing these vapours, and that the process was liable to two accidents. The first was, the loss of no small portion of the

spirit

spirit of nitre which escaped through the orifice of the vessel: the second, the danger to which the operator was exposed from such extremely acrid and corrosive vapours. This process was therefore very defective. Mr Woulfe, an ingenious English chemist, has found means to obviate these inconveniences. Instead of using a receiver perforated with a little hole, he has adopted one with two necks. Into the extremity of this vessel, which is farthest from the receiver, he puts a tube, one end of which being in an horizontal position, makes a right angle with the other, which is vertical and inserted into a bottle. This bottle has in its sides two orifices; each of these receives a syphon which passes into another bottle standing beside the first. The two collateral bottles are joined by means of a syphon with two others, of which the lateral apertures remain open. The first bottle generally remains empty: the collateral bottles contain a quantity of water, in which the lower and longest extremity of the tube which communicates between the two, is immersed: the upper part of the bottles remains empty; and the acid vapour is conducted by the tubes through the bottles. By the use of this ingenious apparatus, the artist is secured from all danger, and nothing is lost. The nitrous acid in vapour passes through the retort into the first bottles, and is there condensed; and what is not condensed in the first passes into the second bottles, and there unites with the water. From the lateral apertures of the last bottles, there escapes a certain quantity of vital air, which may be received into proper glasses. This apparatus, as here described, possesses one advantage worthy of our notice: When

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the retort is left to cool at the end of the operation, a vacuum is produced in the vessels, and the external air pressing on the water in the outer bottles standing open, forces it through the syphons into the inner collateral bottles; and from these again it passes into the middle bottle standing nearest to the retort. If the first bottle were not empty, or not large enough to contain all the water from the others, the acid liquors would pass into the receiver: and as the strongest nitrous acid is contained in that vessel, it would be mixed with the liquors from the bottles, and therefore would not possess the required strength. This circumstance would be still more inconvenient in other instances of distillation, of which we are hereafter to speak; because it would not simply weaken the strength of the product, but would even alter its purity.

In performing this operation in a laboratory, four pounds of pure nitrate of potash, melted into crystal-mineral, are put into a tubulated stone retort, placed in a reverberating furnace; or tubulated glass retorts may be used in a sand-bath. Two pounds and an half of concentrated sulphuric acid are poured in at once through the aperture, and it is then shut. The apparatus above described, which we suppose to have been prepared and put together on the preceding evening, is to be instantly applied and luted to the retort; it is next to be gradually heated till nothing more comes over. The disengagement of the gas, and its passage into the bottles, serve to direct the operator in conducting the process. If the gas appear to be disengaged with too much rapidity, the heat is then too violent, and must be diminished, otherwise the whole mass in
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the retort will swell up and pass into the receiver: But again, if it pass too slowly, the fire must be increased to prevent the absorption of the gas. This apparatus is therefore happily formed to direct the artist in the management of his process.

The residue, after this decomposition, is sulphate of potash, formed by the union of the sulphuric acid with the alkaline base of nitre. This residue is known in pharmacy under the name of *sal de duobus*, or *arcantum duplicatum*. It is usually a white opaque mass, half vitrified, and filled with cavities produced in it when it was swelled by the heat. This salt is strongly acid, on account of the quantity of sulphuric acid made use of in producing it; and it is the excess of the acid which causes the salt to melt, as we have seen under the history of sulphate of potash. The nitrous acid obtained by this process is very red and fuming, because the intense heat employed in the distillation disengages a portion of vital air. As it is always mixed with a certain quantity of sulphuric acid, it is to be rectified by a new process of distillation on a quantity of nitre equal to one-fourth of its own weight. We must likewise observe, that the nitre made use of on this occasion must be very pure, in order to afford nitrous acid in such a state that we may depend upon its effects. That which is obtained from nitre of the second boiling, contains muriatic acid, and acts with the solvent power of aqua regia. This acid may be purified of the muriatic acid which it contains by a distillation judiciously managed; as is shown by Messrs de Laffone and Cornette (*Mem. Acad.* 1781, p. 653 to 656).

The concrete boracic acid decomposes nitre with the help of heat, disengaging from it the nitric acid in a concentrated state. It appears to effect this decomposition by means of its fixity; which is the opinion of the academicians of Dijon. Yet it must also be ascribed in part to the mutual attraction between the boracic acid and the potash base of nitre.

Nitre of potash is much used in the arts. It is the principal ingredient in gun-powder; of which composition we shall have occasion to speak under the article of sulphur. When burnt with various proportions of tartar, it forms the melting matters called *fluxes*, which are used in the assaying of metals for melting and reducing metallic substances, &c. &c.

It is often used in medicine as a quieting, cooling, refreshing, diuretic, antiseptic medicine, &c. It is given in any kind of drink, in doses of—from ten or twelve grains to half a dram and more. Physicians have daily instances of its good effects*.

Species

* Since nitre is a compound of potash with azote and oxigene, all matters affording these three substances, will, of course contribute to its formation; animal matters, by furnishing azote; vegetables, as yielding potash; the air, as supplying oxigene. It effloresces on the surface of uncultivated grounds. It is formed on the pasture grounds of cattle. It is dispersed even in the dust of the roads of Spain. Chestnuts supply a material for its formation. M. Virengue has found, that it is produced in all extracts capable of fermentation. The distillation of nitrate of potash, affords 12000 cubic inches of oxigene, for each lib. of the salt: 7 parts of water, dissolve 1 part of nitre at 60° Fahrenheit: and boiling water dissolves a quantity equal to itself in weight. 100 grains of the crystals of nitre contain 30 acids, 63 alkali, and 7 water.—H.

Species IV. *Nitrate of Soda.*

NITRATE of soda, which has been called *cubic*, *quadrangular*, and *rhomboidal nitre*, is a perfect neutral salt, resulting from a saturated combination of the nitric acid with soda.

This salt generally appears in pretty large and very regular rhomboidal crystals. The name of *rhomboidal nitre* describes it better than that of *cubic nitre*.

Its taste is fresh, and rather more bitter than that of nitre of potash.

Fire decomposes this as well as the preceding salt; but it decrepitates, and does not melt so easily as the other. It affords a mixture of vital air with gas azote, with an alkaline residue like nitre of potash.

It is rather more subject than nitre of potash to alteration from the air, and attracts moisture, though not with much force.

It dissolves in cold water even more readily than the former salt; for two parts of water, at the ordinary temperature of 60° , are sufficient to dissolve one part of nitrate of soda. Boiling water scarce dissolves it in a greater proportion: and therefore, when we wish to obtain it in regular crystals, the solution must be slowly evaporated. If a tolerably clear lixivium of this salt be set aside in a dry place,—at the end of some months it is found to contain rhomboidal crystals, six or eight lines, and sometimes near an inch long. This is usually the happiest process for crystallizing salts that are as soluble in cold as in warm waters.

Nitre of soda detonizes on burning coals, and inflames

flames any combustible body heated along with it,—rather more slowly than nitre of potash.

Siliceous earth disengages the nitric acid, and unites with its base to form glass. Clay also separates the acid, giving as a residue a kind of frit, which becomes porous and opaque after being exposed to a strong heat.

Barytes decomposes it, and leaves the soda pure. Magnesia and lime produce no sensible alteration upon it.

Potash having more affinity than the base of this salt with the nitric acid, attracts it to itself, and forms with it nitre of potash. We obtain conviction of the truth of this fact by a very simple experiment. If a boiling saturated solution of nitre of soda be divided into two portions, and into one of these there be thrown a quantity of caustic potash, the portion which received this addition will deposit, when it cools, prismatic crystals of nitre of potash; while the other into which there was no potash put, will exhibit no crystals at all, because nitre of soda crystallises only by a very slow evaporation.

If concentrated sulphuric acid be poured upon nitrate of soda, it will disengage the nitrous acid with effervescence. Nitric acid is obtained by a distillation of this mixture, as well as from nitre of potash. The other mineral acids act no more on this salt than on the foregoing.

The neutral salts which has been already examined, sulphate of potash and soda, and nitrate of potash, produce no alteration on nitrate of soda. When these salts are all dissolved in the same water, they crystal-

lize separately, each in its ordinary way: Nitrate of potash and sulphate of soda, by cooling; sulphate of potash and nitre of soda, by evaporation. From all these properties it appears, that nitrate of soda differs from nitrate of potash only in its form, its taste, its slight tendency to deliquesce, its being of easier solution, its crystallising by evaporation, and chiefly by its susceptibility of decomposition by potash.

Nitrate of soda has not been yet found in nature. It is always a product of art, and is formed in the five following ways: 1. By the direct combination of the nitric acid with soda. 2. By decomposing with this alkali, earthy nitrates, ammoniacal nitrate, and metallic nitrates. 3. By decomposing muriate of soda with the nitric acid for an intermedium. 4. By decomposing sulphate of soda by the fuming spirit of nitre. 5. By decomposing such nitrous solutions of metals as are susceptible of it, with muriate of soda: In this instance, in proportion as the muriatic acid combines with the metal, separating from it the nitric acid, the separated acid combines with the soda, which has also deserted the acid with which it was before united. All these decompositions will be particularly described in the respective histories of the salts which are liable to them.

Nitrate of soda might be employed for the same purposes as nitrate of potash. But as it does not produce all the effects of that salt, doubtless on account of its having a greater affinity with water, it is not made use of in the arts. Besides, as it is not found in nature, but is merely a product of art, no attempt has been made to apply it to any particular use. A sufficient
number

number of experiments has not yet been made on this salt to make us acquainted with all its properties*.

Species V. *Muriate of Potash.*

MURIATE of potash, which was formerly called *febrifuge salt of Sylvius*, is a saturated combination of the muriatic acid with potash. It has been improperly named *regenerated marine salt*; for the nature of its base renders it different from that salt. Its crystals are cubic, but always of a confused appearance, and rather an irregular form. Its taste is saline, pungent, bitter, and disagreeable. When exposed to fire, it decrepitates; that is to say, its crystals break into small pieces; which is occasioned by the sudden rarefaction of the water which enters into their composition. If suffered to remain in the fire after decrepitation, it melts and is volatilised, but not decomposed. It may be used as a flux for earths and metallic substances. Its chief use in such cases is to cover the matters to be melted, and by this means fix the action of other fluxes employed, hindering them from becoming volatile, and preventing such alterations as might be occasioned by the access of air.

Muriate of potash is subject to little alteration from the air, as it scarce attracts moisture.

About three parts of cold water are necessary to maintain in solution one of this salt; nor has hot water any greater power of dissolving it. For this reason a slow evaporation is used, to give it in crystals. It is

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* 100 grains nitrate of soda, contain 28.80 acid, 52.09 alkali, 21.11 water.—H.

one of those salts which it is very difficult to obtain in regular crystals of a certain size.

Clay seems to decompose it in part: for muriatic acid may be obtained by distilling this salt with the clays in the neighbourhood of Paris. That operation indeed affords but a small quantity of the acid, and its result is very different from that which nitrate of potash affords. Sand is also known to act in the same manner as clay on muriate of potash.

Barytes, according to Bergman, seizes the acid, leaving the potash in a separate state. Magnesia and lime produce no alteration on this salt.

The sulphuric and the nitric acids disengage the muriatic with effervescence*. This phenomenon is the more striking, if the potash be dry. Muriate of potash, after decrepitating, and losing the water of its crystals, gives a very considerable effervescence with the concentrated sulphuric acid, and the mixture becomes very warm. Where these decompositions are performed in retorts, muriatic acid passes into the receiver,

* We have already observed, when speaking of the decomposition of nitre of potash by the concentrated sulphuric acid, that the nitrous acid is then disengaged with a lively effervescence. We find the muriatic acid exhibiting the same phenomenon; in a much more eminent degree indeed, because this acid has a very strong tendency to assume the gaseous state. This is the general cause of all effervescences, the nature and distinctions of which have, till of late, been but very imperfectly known. It was formerly thought that they were owing to the disengagement of air: we now know them to be produced, not by air, but by all bodies which have any tendency to the state of aëriiform aggregation; and thus we have shown, that the ebullition of water may be considered as a sort of effervescence. As this truth needs to be frequently repeated, in order that it may become generally known, we shall take occasion to recur to it several times when treating of the different neutral salts which admit of decomposition by acids.—F.

ceiver, and the residue in the retort is found to be sulphate of potash,—if the sulphuric acid was employed to effect the decomposition ; but if the nitric acid was used, aqua regia is obtained in the receiver, and the residue is nitre of potash. The boracic acid likewise decomposes muriate of potash by distillation, disengaging the muriatic acid. As all of these operations are done with muriate of soda or marine salt, we shall give a more particular account of them under that article. Neither the fluoric nor the carbonic acid acts in any way on muriated potash.

Neither sulphate nor nitrate of potash or soda acts upon this salt. When all are dissolved in the same water, each of them is crystallised separately and in its own way.

Muriate of potash is frequently met with in nature ; but never much of it together. It is found in sea water, and in the water of salt springs ; sometimes, though not often indeed, it is met with in the same places where nitre of potash is found ; it is also found in ashes of vegetables, and in some animal humours. Art produces it, 1. By a direct combination of the muriatic acid with potash ; 2. By decomposing earthy, ammoniacal, or metallic muriates by the same alkali ; 3. By decomposing sulphate or nitrate of potash, by means of the muriatic acid, as M. Cornette has shown.

This neutral salt was formerly administered as an excellent febrifuge. But it possesses not this property otherwise than in common with all bitter salts. Sulphate of potash or soda is now preferred to it.

Muriate of potash is applied to no use in the arts.

Its disagreeable taste hinders it from being used, like muriate of soda, for seasoning. But it has all the chemical properties of that salt; and the only difference between them is, that muriate of potash has a bitter taste, is more difficult of solution, is unalterable by the air, and is irregularly crystallised. We shall therefore insist no more upon its history *.

Species VI. *Muriate of Soda.*

MURIATE of soda, better known under the name of *culinary* or *common salt*, is a perfect neutral salt, formed by a saturated combination of the muriatic acid with soda. The reader will perceive that the nomenclature which we have hitherto used, renders a definition of the nature of these neutral salts almost unnecessary; as the name of each is expressive of its nature.

This salt abounds in nature more than any other species. It is found in vast masses in the interior parts of the earth, in Spain, Calabria, Hungary, and Muscovy, but more especially at Wieliezka in Poland, near the Crapack mountains †. In the last of these places the
mines

* 100 grains of muriate of potash, contain 29,68 acid, 63,47 alkali, and 6,85 water.—H.

† It is found also in *Switzerland* and *Tyrol*, and at Northwich in Cheshire in England: and it has been inferred from the existence of the salt springs in *Lorraine* and *Franche-Comté*; that there are salt mines in the bowels of the earth, in these districts of the French territory.—Strata of fossil salt probably owe their origin to the natural desiccation of lakes of salt water, or from the precipitation of the salt, by a natural process in such lakes. For a good account of the manner of working salt mines, See *Memoire sur le Sel Marin, par M. Hassenfratz; les de Chimie*, tom. XI. p. 65.—H.

mines are of vast extent, and the muriate of soda is found in prodigious masses. This salt, as it exists in the earth, is generally irregular, and seldom crystallised ; it is usually more or less white, but sometimes coloured : in this state it is called *sal-gem*, having often the transparency of the crystals known under that name. The waters of the sea, as well as of some lakes and rivers, contain this salt. From these waters it is obtained by four general processes.

The first is spontaneous evaporation by the heat of the sun. This method is used in our southern provinces, in Languedoc, at Peyrac, Pécays, &c. Trenches are cut on the sea shore, and very compactly lined with clay : within these trenches little walls are built, dividing them into certain compartments, yet leaving a general communication. When the tide flows, the trenches are filled with water, which is retained in them by the walls forming a kind of sluice-gates. Care is taken that the layer of water retained be thin enough to be readily evaporated by the rays of the sun. As soon as a saline pellicle is formed, it is broken, and the fragments fall to the bottom ; and the same process is repeated till the water be entirely evaporated. The salt is then gathered with rakes, and laid in heaps to dry. This salt contains a mixture of all the other salts that exist in a state of solution in sea-water, such as sulphate of soda and magnesia, muriate of magnesia and lime : it is also contaminated with a portion of clay from the bottom of the trench : and, lastly, small globules of iron and mercury are found in it. The existence of the latter in it may be easily shown by leaving a small piece of gold among the salt for some time : it becomes evi-

dently whiter. This salt being very impure, is known under the name of *sel de gabelle*.

In the northern provinces of France, in Normandy and Brittany, this salt is prepared by an artificial evaporation by fire. In Avranches they take the quicksands among which the sea water has deposited saline crystals, and wash them in the smallest quantity possible of sea water, in order that no more may be used than what is necessary to dissolve the salt : This salt water is then put into lead vessels, and evaporated to dryness. This salt is very white, and purer than that prepared by evaporation in trenches. Guettard has given a careful description of the whole process in the *Memoirs of the Academy* for the year 1758.

In Lorraine and Franche-Comté there are many salt springs. The quantities of muriate of soda which those springs contain in proportion to the quantity of water are various. At Montmorot, in the last of these provinces, both spontaneous evaporation and evaporation by fire are used in the preparation of this salt. For that purpose, the well-water is conveyed by pumps into a large reservoir placed at the top of a shed of a peculiar construction. Under this shed are suspended boards covered with little faggots of thorns. The water falling upon these faggots through small cocks, is divided into very minute drops : and as it thus exposes a great deal of surface to the air circulating rapidly under the shed, nearly two-thirds of it is evaporated. What is deposited on the faggots is sulphate of lime or selenite. And when the liquor, upon trial with an instrument for the purpose, is found to be charged with salt to a certain degree, it is conveyed
into

into large iron boilers supported by bars of the same metal, which cross the bottoms of the vessels, and rest on pieces of wood placed on each side. These boilers which are called *foves*, are very large and shallow, and hold an hundred hogheads * of the salt water. They are then urged with a strong fire. When the water boils up in large bubbles, it is at first muddy, and soon deposits an ochreous earth on its surface in the form of a scum. A salt, which is scarcely soluble, and is called by the workmen *scblot*, is next separated: This salt is nothing but sulphate of lime mixed with a little muriate of soda, sulphate of soda, and earthy muriates. It is conveyed by the circulation of the boiling liquor into little troughs placed round the sides of the boilers for the purpose. These troughs are taken out, and cleared from time to time, till a great quantity of small cubical crystals called by the workmen *pieds de mouches*, are observed floating on the surface of the liquor. They are then taken away for the last time. The fire is diminished, and the muriate of soda is taken off with ladders as fast as it is crystallized. The evaporation is thus continued as long as the water continues to afford crystals. The salt thus obtained is in larger or smaller crystals, according to the slowness or rapidity of the evaporation. The water which remains when crystals are no longer obtained, is called *mother water*, and contains earthy muriates †.

Wallerius

* *Muids*, containing each 380 French pints.

† There is a neutral salt prepared at Montmorot, known under the name of *Epsom salt of Lorraine*; but it is only sulphate of soda, or Glauber salt, the crystallization of which has been disturbed. It is distinguished

Wallerius gives an account of a fourth process for obtaining salt from sea water, which is practised in the north. The water is confined in trenches on the shore; as it forms but a small stratum, the cold soon penetrates through and freezes it. But as that portion necessary for the solution of the salt contained in the whole quantity of water cannot be converted into ice, what remains fluid contains all the salt, and is so concentrated that the most moderate heat causes it to afford muriate of soda in crystals: it is then conveyed into leaden boilers, and evaporated by fire.

The crystals of muriate of soda are very regular cubes of a larger or smaller size, in proportion as the evaporation has been slower or more rapid. They stick together in clusters, forming a kind of ladders, or rather hoppers. Rouelle the elder observed this phenomenon, and has given an accurate description of it in his *Memoirs on Crystallization*. Bergman has given a very ingenious explanation of this fact.

Every body knows the taste of this salt, which is not disagreeable.

When exposed to a brisk heat it bursts and flies into pieces. This phenomenon is called *decrepitation*. It is owing, as we have already observed when speaking of sulphate and muriate of potash, to the sudden rarefaction of the water on which the crystallization depends. When all the water is thus evaporated, the decrepitation ceases, and the salt appears in a powder.

If

distinguished from genuine sulphate of magnesia and Epsom salt, such as comes from England, by its efflorescing in the air, while the latter deliquesces.—F.

If we continue to urge it with a strong heat, it melts after becoming red-hot. If poured in this state on the plane surface of a piece of marble, it congeals into a kind of crystal mineral; but it has not suffered the least alteration, for it may be restored to its original form by solution in water. Fire therefore does not decompose it: if maintained for some time in fusion, it is at length volatilized, but still without alteration. The most intense heat is requisite to bring it into this last state.

Muriate of soda when pure suffers no sensible alteration from air; it rather becomes dry than acquires moisture. It never indeed attracts moisture but when it contains a mixture of muriates with earthy bases, such as in *sel de gabelle*.

It dissolves very readily in water: three parts of the fluid are sufficient to maintain one of this salt in solution. Three ounces and an half of water will entirely dissolve an ounce of the salt. Boiling water does not dissolve it in a greater proportion than cold water; only the solution is rather sooner effected with the help of heat. A very slow evaporation is requisite to give this salt in crystals. The crystallization begins with the formation of a number of small points on the surface of the liquor, which are gradually united in a pellicle, more or less thick; instead of being cubic, the crystals are sometimes square hollow pyramids, resembling hoppers. Rouelle the elder, who paid the greatest attention to all the phenomena of this crystallization, observed the hoppers to be formed in the following manner. When a cube is formed, the little solid sinks a short way beneath the surface of the water; a second is soon
formed,

formed, and connected with the first on one of its sides; and the same phenomenon takes place on the three other sides of the cube. This aggregation of cubic crystals naturally produces narrow inverted pyramids. When these are large they sink to the bottom. If the salt dissolved was very pure, what remains of the water after it has been evaporated till it would afford no more crystals, is entirely without any saline matter. The water of the sea and of salt springs always contains salts with an earthy base. The earth may be precipitated by soda, as we shall have occasion to mention when speaking of earthy neutral salts. Such is the method used for obtaining muriate of soda in a state of great purity.

Muriate of soda appears to contribute to the fusion of glass. It constantly occupies the upper part of the pots in which this matter is melted, and constitutes the greatest part of glass-gall.

It is used for vitrifying the exterior surface of certain pottery wares, and for giving them a kind of cover, by melting down part of their substance with the force of heat communicated through the salt. This is easily effected by throwing a certain quantity of muriate of soda into the furnace. It is volatilized, and by this means spread over the surface of the earthen ware, which, by its intense heat, it causes in part to melt. This is the English way of glazing.

Siliceous earth does not alter this salt, though it appears to promote its fusion.

Pure clay acts with much less force on muriate of soda than on nitres. When distilled with this salt, it affords but a very small quantity of a weak phlegmatic acid.

acid. Distillers of aquafortis, it is true, obtain in this manner the muriatic acid called *spirit of salt*: but they make use of *sel de gabelle* for the purpose; and it contains various muriates with an earthy base; besides, the clay which they use is very impure, and of a deep colour.

According to Bergman's experiments, barytes decomposes muriate of soda, as well as the other alkaline salts; neither lime nor magnesia produces any alteration on muriate of soda. Perhaps these two salino-terrene substances, in combination with the carbonic acid, might separate the component principles of muriate of soda by a double elective attraction.

Caustic potash decomposes muriate of soda, having a greater affinity than soda with its acid. A solution of muriate of soda mixed with potash, gives by evaporation muriate of potash, and the mother water contains pure insulated soda.

Acids act in a very distinct manner on muriate of soda. When concentrated sulphuric acid is poured on this salt, it causes a very considerable motion and a very lively heat. A violent effervescence is observed on the occasion*, which arises from the disengagement of the muriatic acid under the form of gas. This aëriform acid may be distinguished after it has escaped into the atmosphere, as it forms a white vapour with the water in the air, and has, when the vapour

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* Effervescence is as observable in this operation as in the union of the same acid with lime and alkalis saturated with carbonic acid. It takes place, therefore, whenever any body separated from a state of combination is volatilized under a gaseous form: and it may be produced by the carbonic, the muriatic, the nitric, the sulphureous, and the fluoric acids, &c. It must not be ascribed to the disengagement of air.—F.

is very much diluted, a pungent smell not unlike that of saffron. A considerable quantity of muriatic acid gas may be obtained by performing the operation with a pneumato-chemical machine provided with mercury. Glauber was the first who observed that the acid of marine salt might be obtained by decomposing the salt with sulphuric acid, and described the process for obtaining it; on which account this has received the name of *Glauber's spirit of salt*. It was in examining the residue of this operation that he discovered his admirable salt to which we now give the name of *sulphate of soda*.

Almost all writers on the subject, direct the distillation of this salt to obtain the muriatic acid, to be performed by putting a quantity of it into a tubulated stone-retort, and pouring in at the orifice half its weight of concentrated sulphuric acid: A considerable quantity of acid vapour is immediately disengaged, which passes by the extremity of the retort into two balloons prepared to receive it: One of these vessels has a little hole to let the vapours escape, so that they may not burst the vessels. In this operation, as well as in the distillation of the nitrous acid, a considerable quantity of the purest muriatic acid is lost,—escaping in a gaseous form through the hole of the balloon; and the vapours of this acid being so very corrosive, are exceedingly troublesome to the operator. To obviate in part this inconvenience, M. Baumé puts a quantity of water into the retort; and the water being volatilized in the balloon, absorbs part of the muriatic acid gas: But as the water is much less volatile than the acid, there is still a considerable quantity of the

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the acid lost. Mr Woulfe has found means to obviate all these inconveniences, and to procure the muriatic acid in the strongest and most concentrated state of which it is capable, by an expedient directly contrary to M. Baumé's. Instead of volatilizing the water, to make it absorb the vapours of the muriatic acid, he causes the gas to pass through that liquid by the apparatus which we described under the article of nitre.

For every two pounds of muriate of soda and one of the concentrated sulphuric acid that are mixed in the retort, eight ounces of distilled water are put into the collateral bottles. The muriatic acid gas is conducted through the tubes into the water in the bottles, and there dissolved. The water, as it combines with the gas, is heated almost to ebullition, and absorbs a quantity equal to itself in weight. When fully saturated, it ceases to absorb the gas and becomes cold ; but the gas passing into the second collateral bottles, is again immersed in the water which they contain, and heats and saturates it.

This very ingenious process being perfectly consistent with the known properties of the muriatic acid gas, possesses a number of advantages. 1. It secures the operator from the inconveniences to which he is exposed when the acid is diffused through the open air. 2. It prevents the very considerable loss of the acid, which was unavoidable in M. Baumé's process. 3. It gives the muriatic acid in a stronger, more concentrated, and more fuming state than we could possibly have it otherwise. 4. The acid obtained this way is extremely pure, being entirely formed of gas that has been dissolved in water. It is on this account extremely white ; whereas

that which was formerly obtained in the laboratory was always of a citron colour ; a circumstance which even led chemists into a mistake, for they considered this colour as a characteristic property of the acid. That portion of the liquid acid which is in this process condensed in the receiver is yellow, and contaminated with extraneous matters conveyed into it by the water of the mixture, as happened to the whole of what was obtained in the old way. 5. The new method directs the operator what strength of fire to use, and how to conduct his operation by the slower or quicker passage of the gaseous muriatic acid through the water in the bottles. 6. Lastly, what is of more importance than any of its other advantages, it enables us to determine the precise quantity of acid contained in any neutral salt, as not a particle of the acid separated is lost.

The nitric acid likewise decomposes muriate of soda ; but, being volatile, it ascends and unites with the acid of this salt. From this union results the mixed acid known by the name *nitro-muriatic acid*, or *aqua regia*.

Baron has discovered that the boracic acid, with the help of heat, disengages the acid from muriate of soda. The residue, after this distillation, is genuine borax of soda in a very pure state.

Neither the carbonic nor the fluoric acid acts in any distinct manner on muriate of soda.

None of the neutral salts hitherto described by us acts upon this salt. When sulphate and nitrate of potash and soda and muriate of potash are dissolved in the same water with muriate of soda, each of these salts crystallises by itself, and in its own way. Muriate of soda is among the first which are separated in the pro-

gress of the evaporation, and it mixes with a little of the sulphate and muriate of potash; but the sulphate of soda and nitrate of potash remain longer in solution, and are crystallised by the cooling of the liquid. On this account, in Lorraine, the mother-water, from which marine salt has been obtained, is put into vessels, and stirred while it cools, with staves for the purpose; which causes the sulphate of soda to crystallise in a confused manner, in small needles, resembling those of genuine Epsom salt, or sulphate of magnesia.

The uses of muriate of soda are extremely various: It is employed, 1. For glazing some kinds of earthen ware by occasioning a slight fusion of their exterior surfaces. 2. By glass-makers, for whitening and purifying glass. 3. In assaying metallic ores, as a flux to the matters of which the scorixæ are formed, to facilitate the precipitation of the metals, and to defend them from the contact of the atmosphere, so that they may suffer no change from the air.

At present we find it necessary to apply it to a purpose of still more importance than any or these,—for the extraction of soda, which is becoming every day more scarce, and is of essential use in many of the arts. Several people in England possess the secret of obtaining soda from marine salt in the great way*, and practise it in considerable extent.

Some chemists have thought litharge capable of decomposing muriate of soda by simple maceration and cold. It would appear that, in consequence of its con-

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taining

* We understand that the extraction of soda from marine salt is not practised in England to such extent as M. Fourcroy seems to think.—H.

taining carbonic acid capable of attracting soda, and forming with the muriatic acid an insoluble salt, easily separable from the alkaline lixivium, it must act by a double elective attraction ; but the experiments which I have made on this point, convince me that the process is inadequate to the purpose. Scheele observed, that iron immersed in a solution of muriate of soda is coated with soda saturated with carbonic acid. He treated sulphate and nitrate of soda in the same manner, with the same success. He discovered, that quicklime mixed with muriate of soda, if the mixture were deposited in a damp cellar, afforded an effluence of soda and calcareous muriate. This fact was first communicated to the public by Cohausen in the year 1717. M. de Morveau has proved, that these decompositions are effected by means of the carbonic acid ; for if a solution of sulphate and muriate of potash be poured upon lime-water precipitated by the carbonic acid, it becomes clear and transparent ; but when water containing carbonic acid, is poured on a solution of those salts mixed with lime-water, no precipitation takes place. These facts are so many *data*, on which we must proceed in attempts to obtain soda from marine salt, and to form extensive establishments for the purpose.

Muriate of soda is used as seasoning to the articles of our food, and corrects their insipidity. It likewise facilitates digestion, by beginning the putrid alteration of the substances we use for aliment. Though it be fully proved by the experiments of Pringle, Macbride, &c. that when mixed in a pretty large proportion with animal substances, it retards putrefaction, and is powerfully

fully antiseptic, like most other saline matters; yet it acts in a very different manner when mixed with the same substances in a very small proportion, causing them to pass more readily into a state of putrefaction. This is proved by the experiments of the author of the *Essays on the History of Putrefaction*, and by M. Gardanne's experiments.

The salt is not less useful in medicine. In apoplectic and paralytic cases, &c. it is put into the mouth, and used externally in baths, as an excellent stimulant. In most cases it is a powerful discutient. It is strongly recommended by Ruffel (*de Tabæ Glandulari*) for lymphatic tumours, occasioned by a scorbutic habit. I have myself prescribed it successfully for several diseases of that kind. It is purgative when administered in doses of several drams. As the most impure salt is commonly used on all these occasions, its effects are in part to be ascribed to the calcareous and magnesian muriates which it contains *.

F f 2

Species

* The water of the Baltic sea is said to contain $\frac{1}{81}$ of its weight of salt; the water of the sea between France and England contains $\frac{1}{11}$ of its weight of salt. On the coasts of Spain, the water of the sea has $\frac{1}{8}$ of salt. Between the tropics, the sea-water is said to have from $\frac{1}{8}$ to $\frac{1}{11}$ of salt. The *Jeltonic* salt water lake, in the Russian dominions, was once almost solid with salt, so that heavy waggons were driven upon it as upon strong ice. But, in the year 1757, the proportion of the water began to increase. And it has since increased so much, as to form now within the basin, only a lake strongly impregnated with salt.—H.

Species VII. *Borax of Soda, or Super-saturated Borate of Soda* *

BORAX of soda, or common borax, is a neutral salt, formed by the combination of the boracic acid with soda. We get this salt from the East Indies; but its history is very little known. We know not certainly whether it be a product of nature or of art †. If the discovery of the boracic acid existing in a state of solution in the waters of several lakes in Tuscany, a fact which we mentioned in the history of that acid, give us reason to think borax a product of nature, a variety of facts which we shall hereafter mention, concur to show that this salt may be also formed by certain artificial processes, as well as nitre.

Borax of soda appears in commerce in three different states. In the first, it is crude borax, *tinckal* or *chrysocolle*. This we get from Persia; it is in greenish masses which feel greasy, or in opaque crystals, coloured like green leeks, which are prismatic figures of six faces, terminating in irregular pyramids. There are even two kinds of these greenish crystals, differing from each

* Hitherto we have begun with examining the neutral salts formed by the union of the acids with potash. But, in speaking of those into which the boracic acid enters, we are obliged to begin with that which has soda for its base, for it is the only one with which we are well acquainted.—F.

† Kirwan, in his mineralogy, page 206. informs us, that it is dug out of the earth in the kingdom of Thibet, in a crystalline form. In the Philosophical Transactions for the year 1787, we are informed by a letter from Mr Blanc, dated at Lucknow, that the borax of Thibet is formed in a certain valley in that country, by the co-operation of snow and the waters of a lake in the middle of the valley, with a saline matter which abounds over the valley.—H.

each other in size. This salt is very impure, a great many extraneous substances being intermixed in it.

The second species is known by the name of *China borax*. It is rather more pure than the former: it appears in the form of small plates, or in masses irregularly crystallised, and of a dirty white colour: it displays the beginnings as it were of prisms and pyramids confounded together without any symmetrical arrangement. The surfaces of these crystals are covered over with a white dust, which is thought to be of an argillaceous nature.

The third species is Dutch or refined borax. It appears in fragments of crystals, transparent and tolerably pure: pyramids with a number of faces are observed in it; but their crystallisation appears to have been interrupted. This form affords a certain indication of the manner in which the Dutch purify this salt; it is by solution and crystallisation.

Lastly, It is prepared at Paris by Messrs Lesguillers, druggists in Lombard-Street: and their purified borax is no way inferior, perhaps even superior, in purity to the Dutch borax.

Beside these four kinds of borax, M. la Pierre apothecary in Paris has imagined it to be formed in a mixture of soap-suds with dirty kitchen-water, which a certain individual preserves in a small trench, obtaining from it at the end of a certain time genuine borax in beautiful crystals. But this fact, though first communicated to the public ten years since, has not received confirmation*.

F f 3

We

* Ten years, at the date of the publication of the 3d edition of this work.—H.

We are still ignorant therefore in what manner borax is formed ; only it appears to be produced in stagnant waters containing fat matters. Some authors assure us, that it is artificially composed in China, by mixing in a trench, grease, clay, and dung, in alternate layers, watering this collection of matters at proper times, and leaving it untouched for several years. At the end of this time, by forming those matters into a lixivium, and evaporating the lixivium, crude borax is obtained. Others would persuade us, that it is got out of water filtered through copper ore. M. Baumé positively asserts that the former of these processes succeeded very well with him. *Chem. Eper. Tom. II. page 132.*

Purified borax appears under the form of six-sided prisms, two of the sides larger than the rest, with trihædral pyramids. It displays many varieties in its crystallisation. Its taste is stiptic and urinous. It communicates a green colour to syrup of violets, on account of its containing an extraordinary proportion of soda. We leave it in possession of the name of borax, in order to distinguish it from genuine *borate of soda*, which is saturated with the boracic acid : we likewise call it *borax super-saturated with soda*, to indicate the nature of the combination.

When exposed to the action of fire, the water of its crystallisation causes it to melt with great rapidity ; it gradually loses that water, and swells to a considerable bulk. It is then in the form of a light, porous, and very friable mass, known by the name of *calcined borax*. The cause why borax of soda increases in bulk, and assumes a lamellated porous form, on being calcined,

cined, is, that the water which is disengaged into a vaporous state, raises to the surface a portion of the saline substance half dried, and in light thin pellicles; and the bubbles in which it rises, making their way out at the surface, the pellicles become entirely dry, and are arranged one above another with interstices between them. Calcination produces no alteration on borax of soda, as to its component parts: it loses, in undergoing this process, nothing but the water which mixed with it in crystallisation, nearly in the proportion of six ounces to the pound. We can restore to it its original form by dissolving it in water, and causing it to crystallise anew. But if after it has been calcined, we expose it to a continued heat, it melts on becoming red-hot into a very fusible transparent greenish glass; which is sullied by exposure to the air, and melts in water. Even fusion produces no change of nature on borax; we can cause it to resume its original appearance, with all its peculiar properties, by solution and crystallisation.

Air effects no alteration on this salt: it makes it effloresce indeed at the surface by depriving it of part of the water of its crystallisation. But this efflorescence does not take place in the same manner on all the several kinds of purified borax of soda. The borax of China gives a much flighter efflorescence than Dutch borax. Dutch borax likewise gives a more copious efflorescence than the borax purified in Paris. This slight difference depends no doubt on the different processes adopted for purifying it; on the manner in which its crystals contain water, according as they have been more slowly or quickly; and perhaps too on the different

proportions of soda, and the boracic acid, which enter into its composition.

Borax of soda dissolves very readily in water: twelve parts of cold water are necessary to dissolve one of this salt; half that quantity of boiling water will produce the same effect. It is obtained in crystals by cooling the solution; but the most beautiful and regular crystals are formed in the mother-water, when it is left to evaporate slowly, with the ordinary temperature of the atmosphere.

Borax of soda serves for a flux to siliceous earth, and joins with it to form a very fine glass. It is used in the preparation of artificial precious stones.

It likewise causes clay to vitrify, but with much more difficulty, and more imperfectly. This is the reason of its sticking to the crucibles in which it is put to melt.

We are rather unacquainted with the action of pure barytes and magnesia on borax of soda. Bergman, however, ranks those two substances before the alkalis in the tenth column of his table of affinities; which shows that he thinks them capable of decomposing this salt: But in his dissertation, he says, that the affinities of ponderous earth and magnesia with the boracic acid are not yet exactly known.

Lime has actually a greater affinity than soda with this acid. Lime-water precipitates a solution of this salt; but to make it decompose it entirely, we must boil quicklime and borax of soda together: an almost insoluble saline combination of lime with the boracic
acid

Acid is then deposited, and the caustic soda is left in solution in the water.

Potash appears to decompose borax of soda as well as all other neutral salts with a base of mineral alkali. Ammoniac produces no sort of alteration on this salt.

The acids act on borax in a very distinct manner. If into a boiling solution of borax of soda you pour a quantity of concentrated sulphuric acid, taking care to give the liquor a very small excess of the acid, you may obtain from this mixture, by filtrating and cooling it, a very copious precipitate in small bright scales. This precipitate is boracic acid, and by washing it in distilled water, and drying it in the air, it is rendered very pure. By evaporating the solution thus prepared and leaving it to cool, we obtain from time to time new quantities of boracic acid. At last, the product is sulphate of soda, formed by the union of the sulphuric acid made use of on the occasion, with the alkaline base of borax.

The nitric and the muriatic acids decompose borax of soda in the same manner, because they, as well as the sulphuric acid, have more affinity with soda than the boracic acid has. The last evaporations of these mixtures afford nitrate or muriate of soda. The discovery of the boracic acid seems to belong to Beccher, but has been usually ascribed to Homberg, he having in the Memoirs of the Academy for the year 1702, given the first accurate description of a process for obtaining it. That chemist observed this salt to be sublimated in the distillation of a mixture of sulphate of calcined iron with borax of soda and water. Imagining the first of these matters to contribute greatly to its formation,

formation, he gave it the name of *narcotic volatile salt of vitriol*. Lewis Lemery, eldest son to the famous Nicholas Lemery, made many experiments on borax of soda, and discovered in the year 1728, that the boracic acid, then called *sedative salt*, might be obtained from it by means of pure sulphuric acid, and that the muriatic and the nitric acids likewise separated it; but sublimation was the process which he always used. We are indebted to Geoffroy the younger for the first complete analysis of borax. In the year 1732, he proved that the boracic acid might be obtained by evaporation and crystallization; and by examining the residue which remained after these operations, found soda to be one of the principles of borax.

Baron's experiments on this salt, which were laid before the Academy in the years 1745 and 1748, added two important facts to these discoveries: The first, that vegetable as well as mineral acids decomposed borax of soda: The second, that genuine borax may be formed by uniting the boracic acid with soda. The last of these facts proves that the acid is entirely formed in the salt, and that its formation is in no degree owing to the acids employed to decompose the salt.

The fluoric, and even the carbonic acid though one of the weakest, appears to be capable of decomposing borate of soda, and separating the boracic acid. This last acid unites readily with the borax of commerce; its alkaline base requiring, to be fully saturated, rather more of the boracic acid than a quantity equal to the whole weight of the borax. Bergman is even of opinion that this salt is not fully saturated nor properly neutral, and that alkaline properties still continue to predominate in

it, till such time as it receives this additional quantity of boracic acid. The properties of this neutral salt, when thus saturated, have not as yet been particularly examined.

None of the alkaline neutral salts, whether sulphuric, nitric, or muriatic, acts in any manner on borax of soda.

This salt acquires a reddish colour when melted with combustible matters, such as charcoal; but we know not yet what alteration it suffers from these matters.

Borax is of great utility in many of the arts. In glass-making, and the assaying of metals, it is used as an excellent flux. It is used in soldering metals to make the mixture run, which is designed for the solder; and it at the same time softens the surfaces of the metals to be united, and defends them from being calcined by the action of the air. It was formerly much used in medicine, but has gone quite out of use.

Species VIII. *Borate of Potash.*

WE give the name of *borate of potash* to the combination of the boracic acid with potash. It is well known that these two saline substances readily unite, and that from their union results a neutral salt, resembling borax of soda. Of this kind is the residue of nitre of potash, decomposed by the boracic acid. M. Baumé says, that this residue appears in the form of a white half-melted glass, which when dissolved in water, affords small crystals. Borate of potash is therefore fusible, soluble, and susceptible of crystallization, and pure acids decompose it as well as borate of soda. We know nothing more certain of this salt; it should be examined

mined in the same manner as borate of soda. Baron knew the possibility of producing this salt by a direct combination of the boracic acid with potash; he has even distinguished it accurately from common borax, or borax with a base of soda; but not a word has he said concerning the peculiar properties of borax of potash.

Species IX. *Fluate of Soda.*

ACCORDING to the system of nomenclature to which we have conformed from the beginning of this work hitherto, the name *fluate of soda* denotes the combination of the fluoric acid with potash. This neutral salt has, as yet, undergone but a very slight examination—by Messrs Scheele and Boullanger. According to these two chemists, it always appears in a gelatinous form, and is never crystallized. According to Scheele, it becomes, when dried and melted, acrid, caustic, and gelatinous. He compares it in that state to liquor of flints. It appears that fire disengages the fluoric acid; and that the siliceous earth with which it is always impregnated during its preparation, then melts into a soluble glass with the help of the potash.

Fluate of potash dissolves very readily in water. It always retains so large a proportion of this fluid, that it is impossible to make it assume a crystalline form. When it is well saturated, a solution of it produces no alteration on syrup of violets.

We know not in what manner either siliceous, argillaceous, or barytic earth or magnesia, affects this

According

According to Scheele and Bergman, lime has more affinity than potash with the fluoric acid. Throw fluat of potash into lime-water it is instantly decomposed: lime unites with the fluoric acid, forming an insoluble salt, which takes away the purity of the liquor, and is fluat of lime. We shall afterwards see that lime likewise decomposes neutral salts formed of the carbonic acid with fixed alkalis. We have already seen that lime-water precipitates borax of soda; therefore the fluoric is not the only acid which has a greater affinity with that salino-terrene substance than with the fixed alkalis.

The concentrated sulphuric acid decomposes fluat of potash by disengaging its acid; which, according to M. Boullanger, appears in the white vaporous form, and exhales the odour peculiar to the muriatic acid. When this experiment is made in an apparatus proper for distillation, we obtain the fluoric acid, just as we obtain the acids contained in nitre of potash and muriate of soda, when we decompose them with the sulphuric acid.

No inquiry has hitherto been made concerning the action of the nitric and the muriatic acids, or of the known neutral salts, on fluat of potash. This salt is in other respects little known, and is applied to no use.

Species X. *Fluat of Soda.*

THIS is a proper enough denomination for the neutral salt formed by the saturated combination of the fluoric acid with soda. This, like the foregoing salt, has been but very little examined. No body but Messrs
Scheele

Scheele and Boullanger, has said any thing about it ; and they differ in their opinions, as we are about to see.

Scheele asserts, that a combination of soda with the fluoric acid forms a jelly like the preceding salt. Boullanger, on the contrary, says, that the combination affords very small, hard, brittle crystals, of an oblong square figure, a bitter taste, and somewhat styptic. This salt decrepitates on burning coals like muriate of soda ; it dissolves in water, but not readily.

Lime-water decomposes this salt as well as fluuate of potash. The sulphuric disengages the fluoric acid from this salt with effervescence, causing it to rise, like the muriatic acid, in a white vapour of a pungent smell.

From this short account of this salt, the reader may perceive that it is not better known than the last.

Species XI. *Carbonate of Potash.*

THE last two neutral salts which we have to examine, are combinations of the carbonic acid with fixed alkalis.

These substances were never before reckoned among the neutral salts : but we shall immediately see that they are true neutral salts.

What we call *carbonate of Potash*, is a neutral salt resulting from a saturated combination of carbonic acid with potash. Some modern chemists call it *mephitic tartar*, *aërated vegetable alkali*, &c. This saline substance was always taken for pure alkali, till Dr Black's experiments showed it to be a neutral salt. Its old name was *fixed salt of tartar*, because it was obtained
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by the incineration of tartar of wine: It was considered as an alkali, because it possesses some of the properties of alkaline salts. It does indeed convert syrup of violets to a green colour; but borax and several other neutral salts possess the same property: besides, it neither destroys nor weakens the colour of violets like potash. It has an alkaline taste; but the same is distinguishable in borax: only it was distinguished from alkali of soda by its power of attracting the moisture of the air with great rapidity, and its not being susceptible of crystallization. When thus moistened in the air, it received the name of *oil of tartar per deliquium* *. But fixed salt of tartar possesses these two properties only because it is not a perfect neutral salt. Containing still a certain quantity of potash not saturated with carbonic acid, this excess of alkali renders it deliquescent. At present, this salt is obtained in a state in which it is very susceptible of crystallization, and attracts no moisture, but rather effloresces. The Duke de Chaulnes, who has paid much attention to this object, prepares this salt by exposing a solution of potash, either caustic or containing a little of the carbonic acid, in a place full of carbonic acid, as in the upper part of a barrel of beer when it is fermenting. The alkali seizes as much of the carbonic acid as it

* Bohnius relates, that evaporating oil of tartar slowly, by a moderate heat, he obtained, under a saline pellicle, beautiful crystals, which, though exposed to various temperatures, remained six years unaltered (*Dissert. Physico-Chem.* 1656.) M. Montet, a celebrated chemist of Montpellier, who was certainly unacquainted with Bohnius's discovery, has invented a process for crystallising this fixed salt of tartar.—F.

it can absorb, and is regularly crystallised. Its crystals are quadrangular prisms, terminating in very short pyramids with four faces.

Carbonate of potash has an urinous taste, but much weaker than that of the caustic vegetable alkali; for in medicine it is given as a discutient in doses of several grains. This neutral salt is very subject to alteration from fire; it melts easily, and is pretty quickly reduced to an alkali. If it be distilled in a retort with a receiver, and a pneumato-chemical apparatus with mercury fitted to it, the products obtained are, the water of its crystallization, and its acid in an aëriform state. The potash, after this operation, remains in an irregular mass, still retaining, however, a small portion of the acid, which cannot without the greatest difficulty be extracted from it by fire. According to Bergman's analysis of it, carbonate of potash, when saturated with the acid, and regularly crystallised, to which he gives the name of *aërated vegetable alkali*, contains in the quintal twenty parts of the acid, forty-eight of pure alkali, and thirty-two of water. But it is to be observed, that carbonates are more liable than other neutral salts to vary in the quantity of the acid. Yet, as this salt never furnishes regular crystals but when it is fully saturated, Bergman's calculation deserves to be considered as sufficiently accurate.

Carbonate of potash, when fully crystallised, suffers no alteration from air; its crystals neither deliquesce nor effloresce, but remain transparent. This salt, when so pure as to possess this property, being of use in many experiments, it may be proper to let the reader know that it is prepared in the following manner: By
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exposing a lixivium of common potash, very pure and white, and separated from the sulphate of potash which it usually contains, in a shallow dish, in the upper part of a beer barrel ; and the process is the sooner completed, if the potash be continually stirred or poured out of one vessel into another ; and if it be thus kept in contact with the carbonic acid produced by fermentation, till such time as it deposite beautiful crystals of carbonate of potash.

This salt dissolves readily in four parts of cold water, and a rather smaller quantity of warm water will maintain it in solution ; it produces cold as it unites with that fluid. This property which distinguishes neutral from simple salts sufficiently determines the difference between carbonate of potash and pure or caustic potash. It is crystallised by evaporation and cooling conjunctly. When the solution is too much concentrated, it takes the form of an irregular mass, —which often happens in the laboratories.

This salt, as well as potash, serves as a flux to vitrifiable earths ; because fire reduces it to an alkali by expelling the carbonic acid. Besides, when this salt, with a mixture of sand, is violently heated in a crucible, a lively effervescence may be observed at the instant of vitrification ; and that effervescence is owing to the disengagement of the carbonic acid. This fact shows that siliceous earth cannot enter into combination with an alkali saturated with this acid, and that the acid escapes when the vitreous combination takes place. This effervescence attends so invariably the combination of these two substances, that Bergman proposes to try siliceous earth by means of the blow-

pipe, with carbonate of potash, as no other earth exhibits the same phenomenon when heated with this salt.

Clay does not act at all on carbonate of potash ; but the salt reduces that earth to a vitreous frit, though not quite so easily as does caustic potash. Barytes deprives this salt of the carbonic acid.

Lime likewise decomposes it, having a greater affinity than potash with the acid. Lime-water poured into a solution of carbonate of potash, gives a precipitate of an almost insoluble salt, produced by the combination of lime with the carbonic acid ; and the pure or caustic alkali remains dissolved in the water. In pharmacy, this process is made use of for the preparation of the *lapis causticus*, which is nothing but fixed vegetable alkali rendered caustic by lime. Modern discoveries have shown, that Lemery's process for preparing the *lapis causticus*, though followed by many pharmacopœiæ, is very defective. It consists in mixing two pounds of ashes obtained by the combustion of the husks of grapes with lees of wine *, with a pound of quicklime, immersing the mixture into sixteen pounds of water, filtering it, evaporating this lixivium in a copper vessel, melting the residue in a crucible, and pouring it out upon a plain surface. The product obtained by this operation is merely a dirty alkali not very caustic, and containing copper.

Bucquet, sensible of the disadvantages of this process,

* These ashes contain a great deal of vegetable alkali or carbonate and sulphate of potash—F.

cells, has given one, more tedious and expensive indeed, but much more certain and advantageous, especially for preparing very pure potash, which is so necessary in chemical experiments. Take two pounds of very strong quicklime ; pour a little water upon it to reduce it to powder ; add a pound of fixed salt of tartar, and pour upon it as much water as may be sufficient to form it into a paste : When this mixture becomes cool, add to it water to the quantity of sixteen pints, and put the whole into a linen cloth lined with paper ; about twelve pints of a clear liquor will pass through this strainer, and the remained is to be washed with four pints of boiling water to take away all the alkali. This liquor gives no effervescence with acids : but the best test for trying its causticity is to observe whether it clouds lime-water ; for if it contain the smallest portion of carbonic acid, it will infallibly produce that effect. But as, after this first process, it still gives a precipitate with lime-water, when very pure alkali is wanted for nice experiments, the lixivium may be treated with two additional pounds of quicklime. It then passes very clear through the strainer, and becomes so caustic as not to alter the transparency of lime-water. When the alkali is evaporated by fire in the open air, that salt absorbs the carbonic acid contained in the atmosphere ; therefore, to obtain it in a dry form, and very pure, we must evaporate the liquor in a retort. But this very tedious process is not necessary for producing the *lapis causticus* ; for if alkali be of such strength as to corrode the surface of the skin, it is sufficient for the purposes of that preparation. But as dry solid potash, in a state of high purity, is neces-

fary in many experiments, I must here observe, that the caustic alkaline lixivium must be evaporated in close vessels, and that the fire must be very cautiously managed, because the evaporation is attended with considerable difficulty, in regard to the density which the liquor assumes towards the end of the process. The fixed alkali is very white, and does not effervesce with acids, nor destroy the purity of lime-water.

Magnesia does not act on carbonate of potash; for the carbonic acid has a greater affinity with fixed vegetable alkali than with that salino-terrene substance.

The sulphuric, the nitric, the muriatic, and the fluoric acids, decompose carbonate of potash by combining with the fixed alkali, and separating the carbonic acid with effervescence. The acid may be collected under water or mercury. It is distinguishable by the four following characteristics: it is more ponderous than air; it extinguishes lights; reddens tincture of turnsol; and precipitates lime-water.

The boracic acid seems incapable of separating the acid from carbonate of potash cold; but when hot, it effects it with great ease.

The neutral salts which we have examined, neither suffer any alteration from carbonate of potash, nor produce any such effect upon it.

This salt abounds in nature. It is often found in vegetables, completely formed, and is constantly obtained by the incineration of these organic bodies; as we shall have occasion to show when we come to speak of
of

of the vegetable kingdom. Burnt tartar affords it in the greatest abundance. It is also prepared by the detonation of nitre of potash.

Carbonate of potash is much used in the arts. In medicine, it is administered as an aperient and discutient, in obstructions of the mesentery and the urinary passages. It is always given in small doses, and along with some substance of efficacy to moderate its action.

Species XII. *Carbonate of Soda.*

THIS salt, like the foregoing, was formerly thought an alkali. It is, however, a combination of the carbonic acid with mineral alkali. This seems to be the salt which the ancients called *natrum*. It is usually called *salt of soda*, because it may be obtained pure and regularly crystallised by evaporating a lixivium of common soda. Marine alkali is likewise distinguished from vegetable fixed alkali, by its being susceptible of crystallisation and efflorescence, which is owing to its being completely saturated with carbonic acid in its ordinary state.

Carbonate of soda has an alkaline taste; it communicates a green colour to syrup of violets, but does not like caustic soda, finally alter its colour. Its taste is urinous, but not burning, and much weaker than that of pure marine alkali.

This salt is naturally purer than carbonate of potash, and has been long known to be susceptible of crystallisation; a property which may be considered as forming a general distinction between neutral and simple

salts.

salts. Its crystallised form is owing to its containing almost always the quantity of carbonic acid necessary to its saturation and crystallisation.

This salt, when hastily crystallised, exhibits rhomboidal plates, disposed obliquely over one another, like tiles on the roof of a house. When slowly crystallised, it assumes the form of rhomboidal octohædrons, with pyramids truncated near the base, or solid decahædrons, with two acute and two obtuse angles.

This salt generally melts easier than carbonate of potash; for which reason it is used in preference to it in the glass-houses. It loses most part of its acid by heat but still retains a little. Bergman has found, by an exact analysis, that an hundred parts of carbonate of soda, which he calls *aërated mineral alkali*, contain sixteen parts of the acid, twenty of pure alkali, and sixty-four of water:—so that more of the acid is requisite to saturate soda than to saturate potash; and the crystals of the former retain just twice as much water as those of the latter. It is to this extraordinary quantity of water that carbonate of soda owes its crystallising with such facility and regularity, as well as its property of efflorescing.

Carbonate of soda is more soluble than carbonate of potash. It dissolves in two parts of cold or one of boiling water. It crystallises by cooling, but gives much more regular crystals by slow evaporation.

When this salt is exposed to the air, it crumbles down very readily into dust; for the air deprives it of the water of its crystallisation: But it is not altered by this efflorescence; for we can restore it to its primary form by solution in water.

It contributes greatly to the fusion of vitrifiable earths, and forms with them a glass less liable to alteration than that which is in part composed of carbonate of potash, to which it is for this reason preferred in the glass-houses. It has been observed, that when sand unites with this salt, it expels the acid, which escapes with a very observable effervescence, agreeably to what we have remarked of carbonate of potash. It has no more influence on clay than the last salt.

Barytes, as well as quicklime and limewater, decomposes carbonate of soda in the same manner as carbonate of potash, and separates the pure caustic mineral alkali. A solution of this salt poured into limewater produces a precipitate; an effect which is never produced by caustic soda. When pure caustic soda is wanted for nice chemical experiments, recourse must be had to the same process which we described above for preparing the *lapis causticus*.

Carbonate of soda, as well as carbonate of potash, may be decomposed by the sulphuric, the nitric, and the muriatic acids, &c. The carbonic acid may be obtained from it by collecting it into a glass filled with water or mercury.

In Egypt, this salt is found entirely formed at the surface of the earth, as well as in several other places. It is likewise found in the ashes of sea-weeds, but not completely saturated with the acid. To render it more perfectly neutral, it must be directly combined with the cretaceous acid, either by shaking it over some liquor in a state of fermentation, or by receiving into a solution of it a portion of the carbonic acid, separated from



from chalk by the sulphuric acid. It may be also produced by wetting the sides of a vessel with a solution of soda, and then pouring into the vessel a quantity of carbonic acid: the mouth of this vessel is then to be covered with a wet bladder; and at the end of a few hours, the combination is found to be effected,—for the bladder is emptied by the absorption of the carbonic acid, and the sides of the vessel are covered with the salt in regular crystals.

Carbonate of soda may be applied to the same purposes with carbonate of potash. It is much more used in soap and glass manufactories, &c. &c. We should therefore endeavour to procure it in greater quantities, and to extract it in the great way from muriate of soda. We have seen that litharge, which some chemists pretend to be adequate to this effect, does not properly decompose that salt. We have also taken notice of Scheele's having discovered a more entire decomposition of muriate of soda, effected by quicklime and iron, with the help of atmospheric air, and the carbonic acid which it contains. We see that a greater proportion of this acid than what usually exists in the atmosphere, is requisite to promote this decomposition, by exerting its attractive force on the soda.



END OF VOL. I.



